Statistical Indicators
E-46
Breeding Value Estimation for Milking speed

Introduction

It is of importance to know how fast daughters of a specific sire can be milked. Cows that milk too fast have a greater chance of mastitis and may suffer from milk leaking. Cows that milk too slowly have an undesirably long milking time.

From 1991 in the VRV area (Belgium) and 1994 in The Netherlands, cattle breeders that participate in the linear classification program are requested to evaluate their heifers on Milking speed. From April 1994 the breeding values for Milking speed have been calculated on the basis of the data of these surveys.

With the use of milking robots, also known as automatic milking systems (AMS), into dairy farming, a cow's Milking speed can be determined for every individual milking. The advantage of using AMS data is fourfold:
1. data is collected automatically;
2. multiple observations per animal become available;
3. data becomes available quickly after calving;
4. the measurement is objective.

By using AMS data, a multitude of Milking speed data is available that can be used in addition to classification data. From April 2023, breeding values for Milking speed will be calculated both from classification data and AMS data. With Milking speed based on AMS data being the breeding trait, and Milking speed based on classification data being included as a correlated trait.

From the data about Milking speed, the genetic effect of the cow, the so-called breeding value, can be calculated. By using a statistic model, disturbing environmental factors that affect the Milking speed are taken into account. Examples of disturbing environmental factors during the evaluation or measurement of the Milking speed are: the milk yield of the cow and the lactation stage. In this part the calculation of the Milking speed breeding values will be explained. Moreover, the presentation and publication will be discussed.

Selection of data

1. AMS

The Milking speed in the AMS data is expressed in kilograms of milk produced per minute of milking time. The milking time is the amount of time a cow is actually milked, the time from connecting the first milk cup to removing the last milk cup. Pre-treatment and post-treatment are excluded.

The data are used in the breeding value estimation if they meet the following requirements:
1. an animal is female, pedigree registered (S), and the cow's sire is known;
2. an animal has a known residence on the day of milking;
3. an animal has a bloodline less than 50% Belgian White-Blue;
4. the observation is made on an animal in its first lactation;
5. the age at first calving is minimum 610 days and maximum 1095 days;
6. the observation is between day 10 and 350 in lactation;
7. the observation is from an AMS farm, where observations from the AMS are also available the day prior to milking;

8. the milking must not have failed or been refused;
9. the milk yield of the milking is known, with a minimum production during the milking of 0.5 kg and a maximum production during the milking of 30.0 kg, where all four quarters produce milk;
10. the total milking time of the milking is known, with a minimum milking time of 60 seconds and a maximum Milking time of 900 seconds;
11. the Milking speed has a minimum of 0.5 kg/minute and a maximum of 8 kg/minute;
12. the Milking speed of an animal must not deviate more than 4 standard deviations from the average Milking speed of this animal.

The repeatability of the characteristic Milking speed is high and therefore it is not necessary to include all measurements as well as not to make the calculation time of the breeding value estimation too long. Therefore the first milking of each cow and subsequently every twentieth milking are included in the breeding value estimation. This quickly makes 30 to 50 measurements of one complete lactation available per animal. Due to the large amount of data, the selection of data does not affect the calculated breeding values.

2. Classification
Scores are collected via the linear classification program. To this end, Dutch cattle breeders who participate in the linear classification program are requested to evaluate their heifers on Milking speed on a scale of 1 to 9 inclusive. The VRV scores on a scale from 1 – 5 till June 1st 2003 and 1 – 9 from June 1st 2003. The description of Milking speed for the various scores is stated in Table 1.

In the NL animal model for Milking speed the data must comply with the following requirements:

1. the cow must be registered in the herd book (S);
2. the cow (milking heifer) must have calved before 3 years of age;
3. the cow must have a known herd and calving date at the time of classification;
4. the cow must be classified according to the Z, R, Y or F standard;
5. the cow must be in the herd classification system or in an additional classification system;
6. Linear traits are scored from 1 to 9 or 1 to 5;
7. The first classification of cow is used in the breeding value estimation, when a cow is classified more than once as a heifer by the same or different organisations.

Table 1. Description of score for Milking speed as used with the linear classification.
A. The Netherlands and Flanders since 01-06-2003.

very slow		slow		average	fast		superfast	
1	2	3	4	5	6	7	8	9

B. Flanders tilll 01-06-2003,.

very slow	slow	average	fast	superfast
1	2	3	4	5

The difference in scale between the Netherlands and Flanders before 01-06-2003 is solved by scaling all scores from Flanders to the scale 1 – 9. These re-scaled scores are standardised per year, so the average and spread in the data are equal for each year between the Netherlands en Flanders

▪ Use of pedigree information

The use of pedigree information in the animal model for Milking speed is similar to that in the breeding value estimation for milk production traits. See also chapter E-7.

▪ Statistical Model

1. AMS

The calculation of breeding values based on AMS data is done with an animal model, according to the BLUP (Best Linear Unbiased Prediction) technique. When calculating breeding values, confounding influences on the measured Milking speed are taken into account, using the following statistical model:

$$Y_{ijklmnopqr} = HYS_i + YMC_j + DIL_k + AFC_l + HET_m + REC_n + INB_o + A_p + PE_q + Rest_{ijklmnopqr}$$

In which:

$Y_{ijklmnopqr}$: Milking speed for animal *p* in lactation 1, on herd * year * season * box *i*, calved in year * month *j*, with number of days in lactation *k*, calved at age *l*, with heterosis effect *m*, recombination effect *n*, inbreeding effect *o* and permanent environment effect *q*;
HYS_i : herd * year * season * box effect *i* at time of milking;
YMC_j : year * month effect *j* at time of calving;
DIL_k : number of days in lactation *d* * 3 years;
AFC_l : age of first calving *l* in days *a* * 3 years;
HET_m : heterosis class *m*;
REC_n : recombination class *n*;
INB_o : inbreeding coefficient *o*;
A_p : additive genetic effect (breeding value) for animal *p*;
PE_q : permanent environmental effect *q*;
$Rest_{ijklmnopqr}$: residual term of Y*ijklmnopqr* which is not explained by the model.

The effects A, PE and Rest are random, the effects HET, REC and INB are covariables, the other effects are fixed.

The effects in the model

The nine effects in the model are:
1. herd * year * season * box at time of milking;
2. year * month of calving;
3. stage of lactation at time of milking * 3 year;
4. age at calving * 3 year;
5. heterosis;
6. recombination;
7. inbreeding;
8. additive genetic effect (breeding value);
9. permanent environment.

*Herd * year * season * box*

During the season, there is variation in Milking speed. In spring and summer, the Milking speed is higher than in fall and winter. In addition, there is also variation between herds, considering, for example, the adjustment of the AMS (also between AMS's on one farm, if there are more than one). Within a farm there is also variation over time, think for example of a change in the adjustment of the milking robot. Each unique herd * year * season * box is a separate level in the model.

*Year * month of calving*

Animals calving in spring and summer have a slightly higher Milking speed compared to those calving in fall and winter. Each unique year * month is a separate level in the model.

Lactation stage

At the beginning of the lactation, the Milking speed will first decrease, which is caused hormonally. In addition, there is a lot of variation within measurements on an animal in the first days of the lactation

caused by colostrum. For this reason, the first 10 days in lactation are excluded from the breeding value estimation. From about the 10th day, Milking speed increases until day 200 in lactation. From day 200 until the end of lactation, the Milking speed then remains fairly constant. This pattern is also clearly visible in Figure 1. The effect for lactation stage will be considered by three years, then each lactation day is a separate class in the model. An animal that was 40 days in lactation in 2019 will therefore belong to a different class than an animal that was 40 days in lactation in 2016. From the most recent milk date in the data, periods of three years back are formed. If the last period is shorter than two years, this period is merged with the previous period.

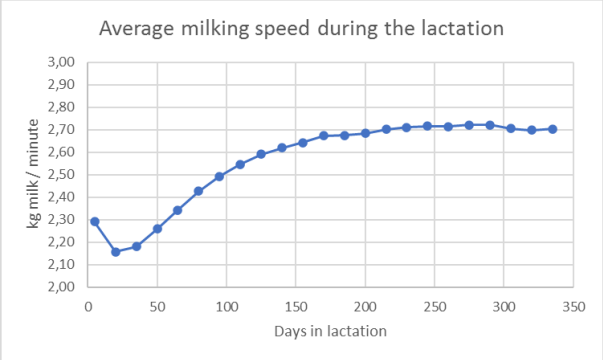

Figure 1. Average Milking speed during the lactation, in classes of 15 days.

Age at first calving

Calving age has an effect on the average Milking speed of an animal. This is shown in Figure 2, where the red line indicates the average trend in Milking speed given the calving age of an animal. Animals calving at a young age (< 24 months) will have a slightly higher average Milking speed compared to animals calving at a later age. Animals calving for the first time at an older age (> 32 months) will on average have a lower Milking speed. Each month will be a separate level in the model, and there are 16 levels in total (calving age in months from 20 to 35). This effect will also be divided into groups of three years.

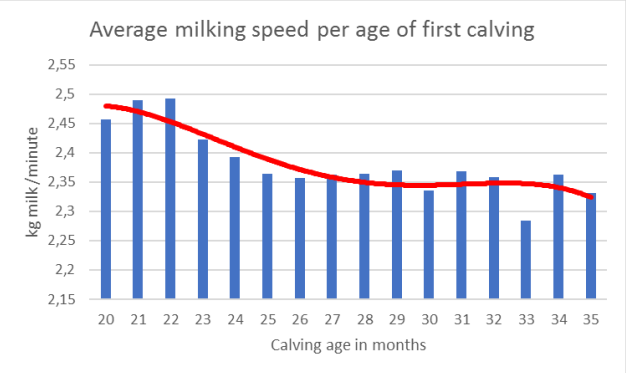

Figure 2. Milking speed per age at first calving in months.

Heterosis and Recombination

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 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. For the formula of heterosis and recombination, see Chapter E-7. One percentage point increase in heterosis leads to a decrease in the breeding value milk speed of 0.005. One percentage point increase in inbreeding leads to a decrease in the breeding value milk speed of 0.049.

Inbreeding

Inbreeding is the making of a mating between two animals whose DNA is more related to each other than the average relatedness in the population. Therefore, inbreeding leads to an increase in homozygosity. By comparing inbred animals with non-inbred animals on a trait, the (negative) effect of inbreeding can be estimated. Inbreeding is not heritable. One percentage point increase in inbreeding leads to a decrease in the breeding value milk speed of 0.049.

Additive genetic effect

The additive genetic effect (or animal effect) is the breeding value. This effect contains the genetic contribution of an animal to the observation and determines the breeding value of an animal. In addition, all information from ancestors and offspring is also used in determining the breeding value.

To calculate the breeding value Milking speed based on AMS data, a heritability of 0.51 is used. The genetic variance is 32.96. Principles of breeding value estimation are explained in part E-7.

Permanent environmental effect
For Milking speed from an AMS system, a cow has multiple observations, as each milking is recorded by the AMS. The repeatability (correlation between successive measurements) of a measurement on the same animal is 0.81. The observations of one cow's Milking speed are determined by the additive genetic effect as well as all other effects as discussed above. Thus, because there are multiple observations on one animal, the observations have more in common than just the additive genetic effect. This extra similarity is called the permanent environment effect, an effect of the constant circumstance a cow is facing. For example, if the cow has already suffered teat damage in her rearing, this may have an effect on her Milking speed when she is lactating. However, this is not a genetic effect and is not among the other fixed effects in the model. Through the use of a permanent environment effect in the model, multiple observations on an animal can be used to arrive at a better estimate of the breeding value. The permanent environment variance is 19.63.

The additive genetic effect and permanent environment effect are random effects, which means that the amount of information available on an animal can be taken into account. If there is little information about an animal (few offspring and few observations on the animal), the additive genetic effect will not vary much from the parental mean, and the permanent environment effect will not vary much from 0.

In addition to the genetic variance and permanent environment variance, there is also the error variance. The magnitude of this variance is 12.22.

2. Classification
The calculation of the breeding values on the basis of the survey system is done with a sire model, in accordance with the BLUP technique (Best Linear Unbiased Prediction). In the calculation of breeding values, disturbing factors to the scores are taken into account, in which the following statistical model is used, based on research by De Jong (1993):

$$y_{ijklmnopqr} = HS_i + CM_j + AGE_k + LST_l + MLK_m + HET_p + REC_q + INB_r + A_n + e_{ijklmnopqr}$$

in which:

$y_{ijklmnopqr}$	: score for Milking speed for a cow, present in herd *i*, calved in month *j*, at age *k* at the time of classification, with lactation stage *l* at time of classification, with a deviation from the herd average of the milk production *m*, with heterosis effect *p*, recombination effect *q*, inbreeding effect *r*, of cow *n*;
HS_i	: herd * season *i*, in which the cow is present. The herd * season is determined by herd * survey date;
CM_j	: month of calving *j*;
AGE_k	: age *k* of the cow at the time of classification;
LST_l	: lactation stage *l* at the moment of classification;
MLK_m	: effect *m* of milk yield (305-days' lactation production) as deviation from the average of the other cows in the farm in the HS*i* class;
HET_p	: heterosis effect *p*;
REC_q	: recombination effect *q*;
INB_r	: inbreeding coefficient *r*;
A_n	: additive genetic effect of breeding value of animal *n*;
$e_{ijklmnopqr}$	: residual term of y*ijklmnpqr* which is not explained by the model.

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

The effects in the model
The nine effects in the model are:

1. herd;
2. month of calving;
3. age at the time of evaluation;
4. lactation stage at the time of evaluation;
5. milk yield;
6. heterosis;
7. recombination;
8. inbreeding;
9. additive genetic effect or breeding value.

Herd
The scores a cattle breeder assigns to his cows via a survey are compared with one another within this survey. Each herd*survey combination forms a new group of cows. Within this group the cows are compared with one another. By incorporating the herd effect in the model the difference in level of scores that cattle breeders makein evaluating cows is taken into account.

Month of calving
It turns out that animals that calve in spring or summer are perceived to milk faster than animals that calved in autumn or winter.

Age
It turns out that animals that are evaluated at younger age are perceived to milk faster than animals that are evaluated at an older age. In total, 22 age classes are distinguished, from which category 1 is adjusting classifications to the age of 20 months and younger. Category 2 to 21 adjusts to the age of 21 to 40 months at classification. In category 22 all cows are included that are 41 months old or older.

Lactation stage
The Milking speed of a cow is evaluated as milking more slowly at the beginning of the lactation than in the second half of the lactation. In total, 13 lactation stage classes are distinguished, one for each month in lactation. In class 13 are all cows classified in month 13 or later in lactation.

Milk yield
A cow with a higher Milking speed, often results in being a better milk producer compared with the other cows at the farm. There are 15 classes in total, in which the deviations are divided into classes of 200 kg of milk.

Heterosis, recombination and inbreeding
These effects are already discussed on page 4 of this E-chapter.

Additive genetic effect of breeding value
For the calculation of breeding value for Milking speed, a heritability for Milking speed of 0.23 is used. For the calculation of breeding values see part E-7.

▪ Publication

Only the breeding values for Milking speed based on AMS data will be published. The breeding value for Milking speed based on classification data is included as a correlated trait, which has a genetic correlation of 0.99.

Breeding values for Milking speed are presented with an average of 100 and a standard deviation of 4. A breeding value above 100 means that the cow has a higher Milking speed than average. With a breeding value below 100, the cow can be expected to have a lower Milking speed average. The breeding value represents the hereditary ability of the trait according to the Dutch definition.

The meaning of 4 point standard deviation
The spread of 4 points in the presented breeding values corresponds to a spread of 0.41 kg/minute. A bull can only pass on half of his breeding value to his daughters. This means that a bull with a breeding value of 104 gives daughters who give on average 0.20 kg milk more per minute than the daughters of a bull with a breeding value of 100. A bull with a breeding value of 110 gives daughters who give on average 0.46 kg milk more per minute compared with the daughters of a bull with a breeding value of 100.

The spread of 4 points in the breeding value Milking speed based on survey data, which is not published but only included as a correlated trait in the breeding value estimation, corresponds to 0.55 points.

Publication requirement
A breeding value for Milking speed is published from a reliability of 25 percent.

▪ Base
See chapter 'Bases for breeding values and base differences'.

▪ Reliability
For the calculation of the reliability for Milking speed, a heritability of 0.51 is used

▪ Literature
De Jong, G, 1993. *Analyse van enquête voor gedrag bij melken, melksnelheid en melk uitliggen bij vaarzen. NRS-notitie 94-0210.* (Analysis of survey of behaviour during milking, Milking speed and milk leaking with heifers. NRS-note 94-0210).

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(Milking speed and robot efficiency based on robot data. R&D-NRS/OND/PROJECT/student-onderzoek/student_Anniek_Gerrits_AMS_melksnelheid_efficiëntie.)

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