Statistical Indicators

E-34
Breeding Value Estimation Ketose

▪ Introduction

Ketosis is one of the most common disorders in dairy cows during the early stages of lactation. In the period until 60 days after calving, dairy cows are often lacking in energy, which can cause metabolic diseases such as ketosis. Ketosis is characterised by an increased level of ketone bodies and health problems like anorexia (Oetzel, 2012). In addition, it has been demonstrated that ketosis negatively affects milk production and reproduction. Ketosis can therefore lead to economic loss due to an increase in the forced removal of animals or higher vet fees (Weller, 2013).

Milk beta hydroxybutyric acid (mBHBA) and milk acetone, in combination with the ratio between milk fat and milk protein, form indicators for establishing ketosis in dairy cows (Van der Drift, 2012 and 2013). Since late May 2012, mBHBA and acetone have been routinely measured during regular Milk Production Recording (MPR).

In addition to environmental factors (season and management) and animal factors (parity), genetics also play a role in the likelihood of contracting ketosis. Ketosis has been shown to be a hereditary disease, with a degree of heritability of about 20%. In addition, there is enough variation in the population to enable selection and therefore to reduce the prevalence of ketosis in the cow population.

Now that data is routinely available for determining ketosis, it makes good sense to estimate breeding values for ketosis. The ketosis determination is taken from the MPR module and is based on three indicators: milk acetone, mBHBA levels, and the fat/protein ratio in the milk measurement. Corrections are also made for season and parity. Selection on the basis of this ketosis breeding value enables the prevalence of ketosis in the herd to be reduced, resulting in a lower incidence of ketosis in the future. Less ketosis brings both animal welfare and economic benefits.

▪ Trait and breeding goal

To estimate the ketosis breeding value, acetone and mBHBA are measured and ketosis is derived from this. In the breeding value estimation, the traits are divided into parity 1, parity 2 and parity 3+. Figure 1 shows the incidence of ketosis per parity based on daughter averages per bull. (The parities are then combined into an overall breeding value.) The breeding goal is to reduce the incidence of ketosis in the dairy cow population.

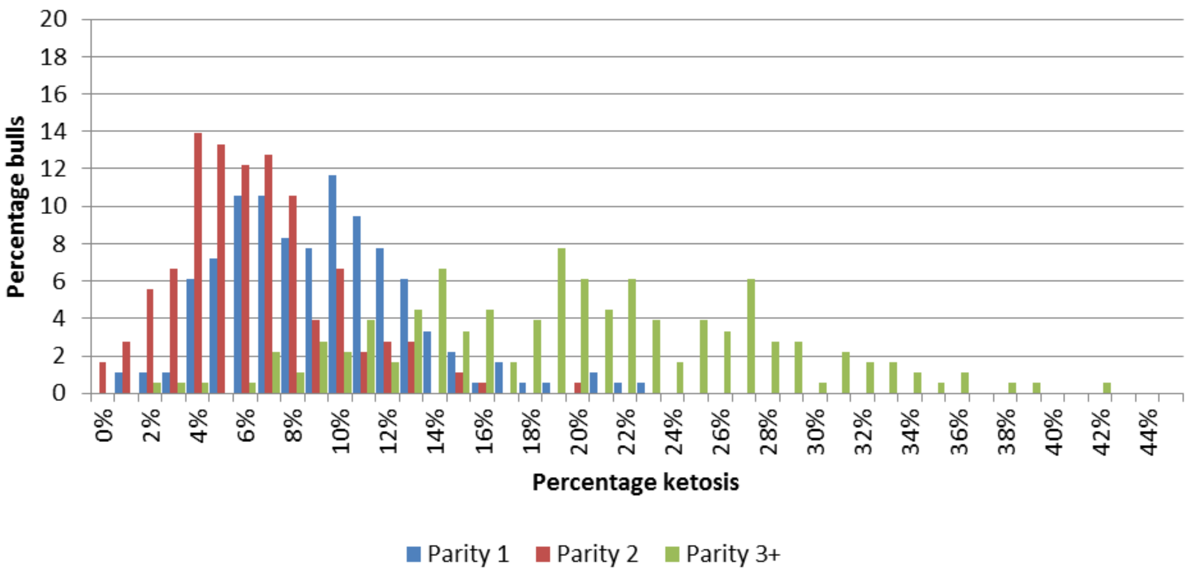

Figure 1. Incidence of ketosis based on daughter averages at bull level for parity 1, parity 2 and parity 3+

Data

Observations

During MPR, ketosis is not measured directly in the milk but is based on milk acetone and mBHBA measurements, as well as the fat-protein ratio on the lactation test day. The data is delivered at test day level but is analysed at lactation level for the ketosis breeding value estimation. Acetone and mBHBA measurements have been performed routinely since the summer of 2012.

Day productions must meet the following requirements:

- A cow must be herd book registered (S) and the cow's sire must be known;
- Only official (approved) day productions are included. Day productions collected by farmers themselves are also acceptable;
- Only day productions from day 5 to day 60 are included;
- The age at calving must be at least 640 days;
- Fat and protein percentages must be below 10%;
- The cow must have a known place of residence on the lactation testing day.

Observations for ketosis, acetone and mBHBA are transformed so that the frequency distribution of the measurements can be better allowed for. Acetone and mBHBA measurements are log transformed. Ketosis is derived from acetone, mBHBA and the fat/protein ratio, and the calculated value is then log transformed.

Statistical model

The ketosis breeding value is estimated with an animal model, following the BLUP (Best Linear Unbiased Prediction) technique. The indicator traits of acetone and mBHBA are analysed at the same time. The correlations between the traits are used for this purpose. The breeding value estimation is therefore a multiple trait breeding value estimation. The reason for including acetone and mBHBA in the breeding value estimation is that these traits are good predictors of ketosis. Inclusion of these predictors should improve the reliability of the ketosis breeding value.

Various statistical models are used for the different traits:

$Y1_{ijklnopqr} = BJ_i + JM_j + DIM_k + LFTD\_K_l + HET_n + REC_o + A_p + PERM_q + Rest_{ijklnopqr}$
$Y2_{ijknopqr} = BJ_i + JM_j + DIM_k + HET_n + REC_o + A_p + PERM_q + Rest_{ijknopqr}$
$Y3_{ijkmnopqr} = BJ_i + JM_j + DIM_k + PAR_m + HET_n + REC_o + A_p + PERM_q + Rest_{ijkmnopqr}$

where:

$Y1_{ijklnopqr}$: Observation for ketosis, acetone or mBHBA in heifer p, with herd – measurement year i, measured in year – month j, days in milk at measuring k, age at calving l, with a heterosis effect n and recombination effect o;
$Y2_{ijknopqr}$: Observation for ketosis, acetone or mBHBA in young cow p (parity 2), with herd – measurement year i, measured in year – month j, days in milk at measuring k, with a heterosis effect n and recombination effect o;
$Y3_{ijkmnopqr}$: Observation for ketosis, acetone or mBHBA in old cow p (parity 3+), with herd – measurement year i, measured in year – month j, days in milk at measuring k, in parity m, with a heterosis effect n and recombination effect o;
BJ_i : Herd – year of test day i;
YM_y : Year – month of test day j;
DIM_k : Days in milk (5 – 60 days) on test day k;
$LFTD\_K_l$: Age of heifers at calving l (parity 1);
PAR_m : Parity of older cows m (parity 3+);
HET_n : Heterosis category n;
REC_o : Recombination category o;
A_p : Additive genetic effect (or breeding value) of animal p;
$PERM_q$: Permanent environment effect of animal p;
$Rest_{ijklnopqr}$: Residual of $Y1_{ijklnopqr}$ not explained by the model;
$Rest_{ijknopqr}$: Residual of $Y2_{ijknopqr}$ not explained by the model;
$Rest_{ijkmnopqr}$: Residual of $Y3_{ijkmnopqr}$ not explained by the model;

The effects A, PERM and Rest are random effects, HET and REC are co-variables, and the other effects are fixed effects.

Effects in the model

The effects in the model are:

1. Herd x year of test day
2. Year x month of test day
3. Days in lactation
4. Age of calves, for parity 1 only
5. Parity, for parity 3+ only
6. Heterosis
7. Recombination
8. Cow
9. Permanent environment

Herd – year

There are great differences in the percentage of animals with ketosis between farms, as shown in figure 2. Farms with a ketosis percentage of 40% or higher are summarised in the category ≥ 40. The ketosis level on a farm can also change over time. This is taken into account by comparing ketosis on a farm over the course of a year.

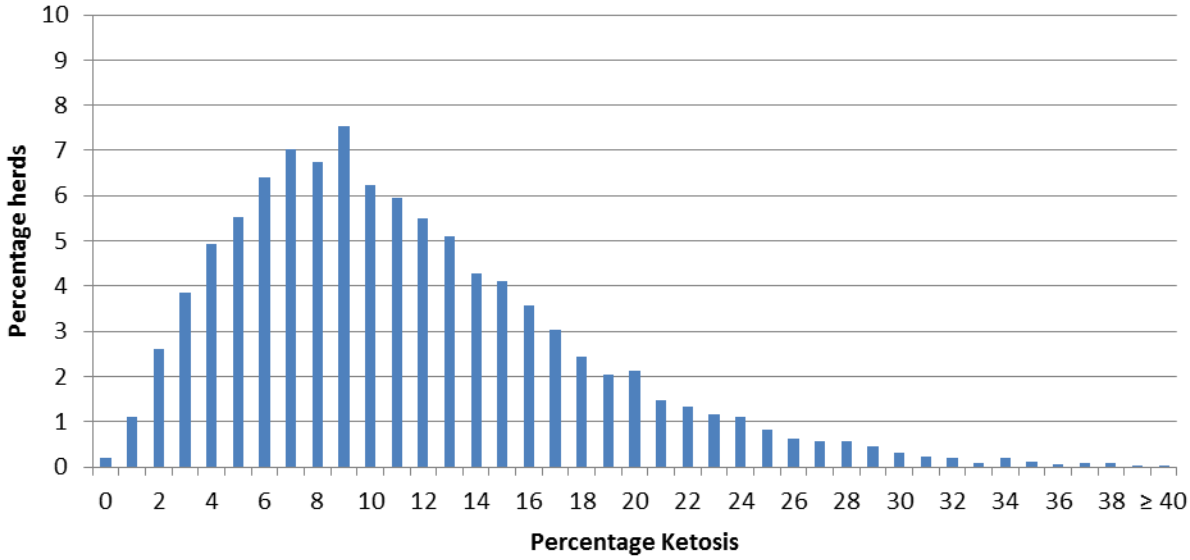

Figure 2. Frequency distribution of ketosis percentage at herd level

Year – month

The ketosis percentage does not remain constant every month; strong seasonal effects can be observed. Differences in the ketosis percentage per month are shown in figure 3, in which the ketosis percentage is shown at record level. The ketosis percentage rises sharply from March and stays high until August. A strong drop in the ketosis percentage can be observed in September. The ketosis percentage remains relatively low until February.

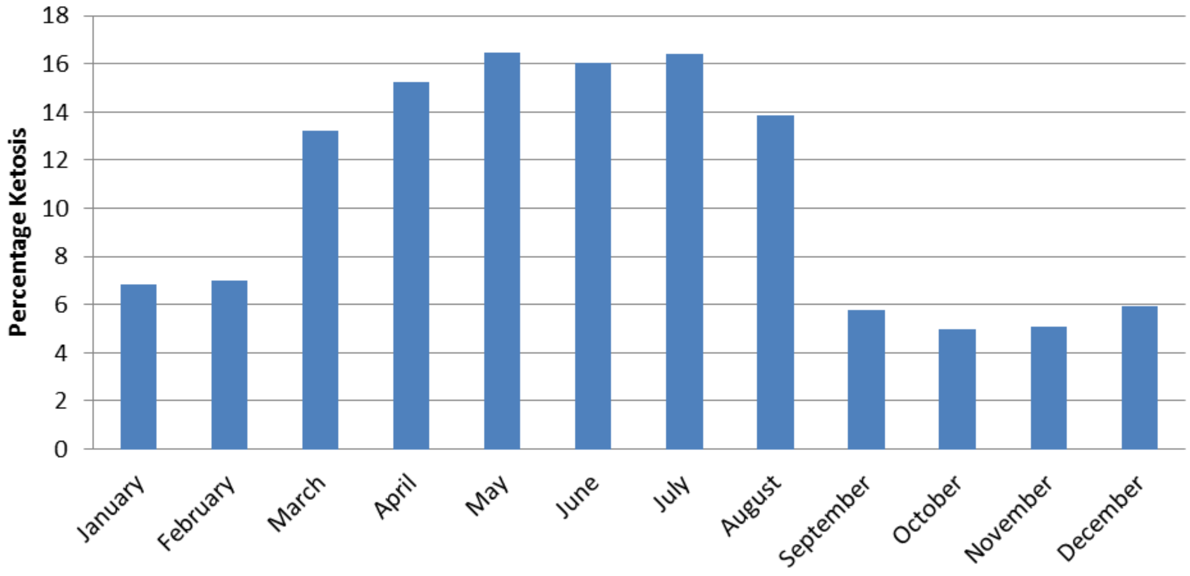

Figure 3. Frequency distribution of ketosis percentage per month at record level

Lactation stage

When analysing ketosis, the lactation stage (number of days the cow is in production) at the time of the milk measurement is taken into account. This is because the lactation stage has an effect on ketosis; this effect is shown in figure 4. The graph is shown at record level. Where an animal has multiple observations, these have been analysed individually. The ketosis percentage is highest around day 10 and drops as the number of days in lactation increases.

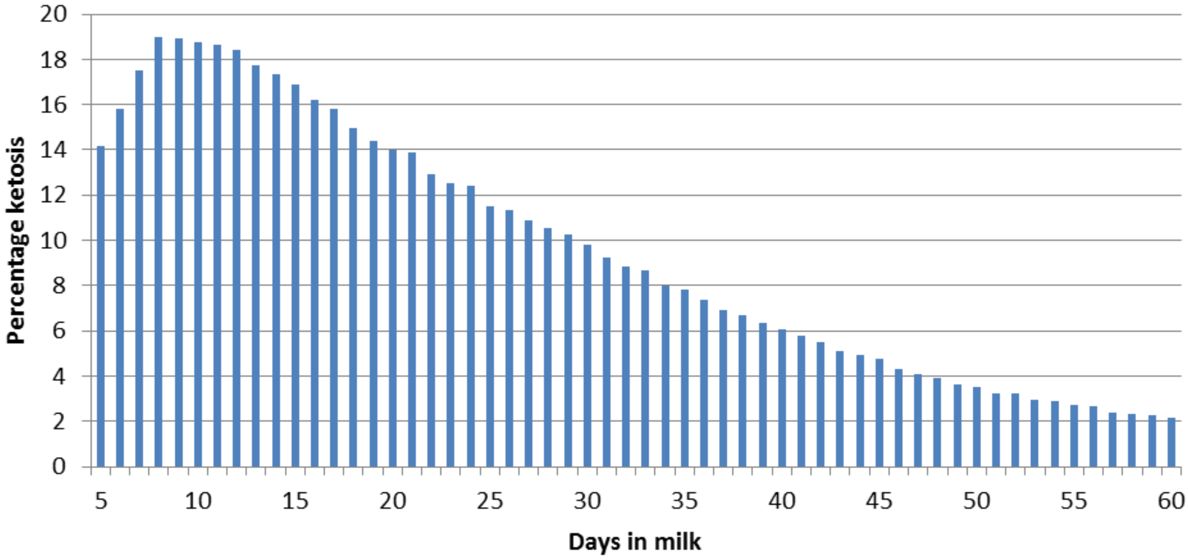

Figure 4. Frequency distribution of ketosis percentage at record level for number of days in lactation

Age at calving

The ketosis analysis takes account of the age at which a heifer has calved. This is because the age at which heifers calve has an effect on the occurrence of ketosis; this effect is shown in figure 5. Figure 5 shows that the ketosis percentage among heifers that calve at an older age is higher than that of heifers that calve young. There are 18 age categories for calving: category 1 corrects for calving at 20 months and younger. Categories 2 to 17 correct for calving between 21 and 36 months. Category 18 contains all heifers that calve at 37 months or older.

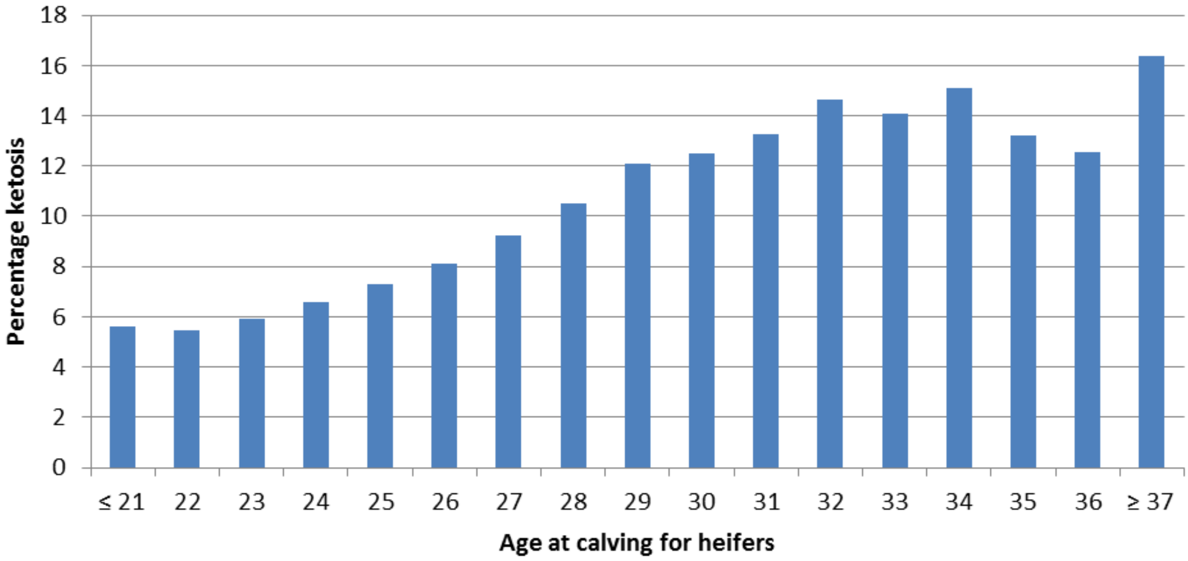

Figure 5. Frequency distribution of ketosis percentage for heifer calving age in months

Parity

In the analysis of ketosis in older cows (parity 3 and higher), the number of calvings is taken into account. Animals in parity 3+ are analysed in one group, but there is a clear difference in the ketosis percentage between lactations. The differences in the ketosis percentage are shown in figure 6. This figure is based on the whole cow population.

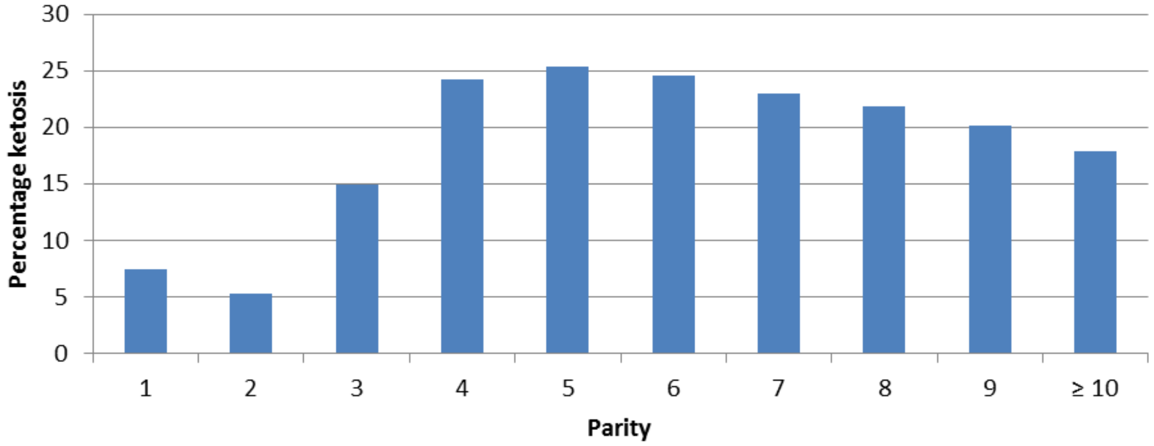

Figure 6. Frequency distribution of ketosis percentage by parity

Heterosis and recombination effect

Heterosis and recombination effects play a role in the cross-breeding of breeds. These are genetic effects which are not passed on to offspring. Research shows that a correction must be made for these effects. The size of the heterosis is defined as the difference in level of the trait in the cross-breeding with the average of the parent breeds. Recombination is the loss of the generally positive effect of heterosis and occurs when the crossbred product obtained earlier is crossed back with one of the parent breeds.

The effect of heterosis on the ketosis breeding value is a reduction of 0.18% for lactation 1, 0.02% for lactation 2, and 0.45% for lactation 3+, for animals that have 100% heterosis.

Cow

This is the additive genetic effect or breeding value – the effect that matters in the end. The variable *animal* contains an animal's genetic contribution to the observation and determines the breeding value of an animal. All the information on ancestors and progeny is also used in determining the breeding value.

Permanent environment

Ketosis occurs at the beginning of lactation and is determined on the basis of acetone and mBHBA measurements in day 5 to day 60 after calving. Multiple milk samples may have been taken from a cow in this period. Milk measurements in a cow have more in common than genetics. This additional agreement is known as the permanent environment effect, an effect of the constant conditions in which a cow is kept. Using a permanent environment effect in the model enables multiple observations on an animal to be used in order to obtain a better estimation of the breeding value.

▪ Traits

A total of 9 traits are analysed in the ketosis breeding value estimation, namely ketosis, acetone and mBHBA for 3 lactation groups (1, 2 and 3+).

The heritability levels, repeatability and genetic variance are shown in table 1. The traits of acetone and mBHBA are used in the breeding value estimation because they are good predictors of ketosis. The genetic correlations with ketosis are also high; the traits of acetone and mBHBA are therefore good predictors and contribute to the reliability of the estimation. Genetic and error correlations are shown in table 2, and permanent environment correlations in table 3.

Table 1. Heritability levels (h^2), repeatability and genetic deviation for the traits

Trait	h^2	Repeatability	Genetic variance
Ketosis 1	0.16	0.40	0.81
Acetone 1	0.21	0.48	9.05
mBHBA 1	0.24	0.52	11.61
Ketosis 2	0.13	0.40	0.62
Acetone 2	0.18	0.43	7.24
mBHBA 2	0.22	0.49	10.57
Ketosis 3+	0.18	0.44	1.03
Acetone 3+	0.17	0.45	9.33
mBHBA 3+	0.20	0.48	11.94

Table 2. Genetic correlations (below diagonal) and error correlations (above diagonal) between ketosis, acetone and mBHBA per parity

	Ketosis 1	Acetone 1	mBHBA 1	Ketosis 2	Acetone 2	mBHBA 2	Ketosis 3+	Acetone 3+	mBHBA 3+
Ketosis 1		0.82	0.80	0.00	0.00	0.00	0.00	0.00	0.00
Acetone 1	0.84		0.87	0.00	0.00	0.00	0.00	0.00	0.00
mBHBA 1	0.79	0.86		0.00	0.00	0.00	0.00	0.00	0.00
Ketosis 2	0.81	0.67	0.73		0.79	0.79	0.00	0.00	0.00
Acetone 2	0.74	0.85	0.81	0.83		0.87	0.00	0.00	0.00
mBHBA 2	0.69	0.76	0.86	0.73	0.84			0.00	0.00
Ketosis 3+	0.58	0.54	0.62	0.74	0.64	0.72		0.85	0.81
Acetone 3+	0.62	0.77	0.74	0.78	0.91	0.84	0.80		0.88
mBHBA 3+	0.70	0.74	0.82	0.80	0.87	0.94	0.74	0.88	

Table 3. Permanent environment correlations between ketosis, acetone and mBHBA per parity

	Ketosis 1	Acetone 1	mBHBA 1	Ketosis 2	Acetone 2	mBHBA 2	Ketosis 3+	Acetone 3+
Acetone 1	0.85							
mBHBA 1	0.85	0.93						
Ketosis 2	0.68	0.41	0.48					
Acetone 2	0.51	0.64	0.66	0.84				
mBHBA 2	0.57	0.62	0.71	0.82	0.92			
Ketosis 3+	0.61	0.37	0.43	0.63	0.47	0.54		
Acetone 3+	0.41	0.64	0.53	0.50	0.67	0.66	0.89	
mBHBA 3+	0.50	0.62	0.63	0.57	0.67	0.73	0.86	0.95

▪ Ketosis breeding value

The breeding value intended for publication is the overall breeding value for ketosis. Besides the overall ketosis breeding value, the overall acetone and mBHBA breeding values are also estimated. The overall breeding values are calculated from the breeding values for parity 1, parity 2, and parity 3 and higher (3+):

$$FW_i = 0.41 \times FW_{i1} + 0.33 \times FW_{i2} + 0.26 \times FW_{i3+}$$

where:
FW_i : breeding value for ketosis, acetone or mBHBA.

The derivation of the factors (0.41, 0.33 and 0.26) is described in E-chapter 7. The weighting factors for the first three lactations are also determined.

The heritability levels and genetic deviations for the overall traits are shown in table 4.

Table 4. Heritability levels (h^2) and genetic deviation for the overall traits

Trait	h^2	Genetic variance
Ketosis overall	0.24	0.64
Acetone overall	0.31	7.71
mBHBA overall	0.34	10.39

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

▪ Base

Breeding values for ketosis are presented on three different bases: black and white base, red and white base and local base.

Black and white base (Z)
Black and white herd book registered cows born in 2010 with at least 87.5% HF blood and 12.5% or less FH blood, with at least one observation in the breeding value estimation.

Red and white base (R)
Red and white herd book registered cows born in 2010 with at least 87.5% HF blood and 12.5% or less MRY blood, with at least one observation in the breeding value estimation.

Local base (L)
Herd book registered cows born in 2010 with at least 87.5% MRY blood and 12.5% or less HF blood, with at least one observation in the breeding value estimation.

An observation is a known measurement of ketosis in a lactation. Every five years, in a year divisible by 5, the reference year for the basis is moved up 5 years.

The standard deviation of the breeding values is determined by the black and white base animals. In this case the standard deviation in breeding values is calculated, with standardisation to a reliability of 80%. This means that a 4-point standard deviation is equal to 0.9 x genetic deviation. The use of one standard deviation for the three different bases has the advantage that there is only a difference in level between the bases and not in the deviation.

The differences in the bases for ketosis overall are shown in table 5.

Table 5. Differences in bases for ketosis

Trait	*Z > R*	*R > L*	*Z > L*
Ketosis overall	-1	-5	-6

Publication

In publications, the breeding value for ketosis overall is used with parity 1, parity 2 and parity 3+ being combined into one ketosis breeding value. The parities are weighted in the ratio 0.41, 0.33 and 0.26 for parity 1, parity 2 and parity 3+ respectively.

Presentation
The breeding value for ketosis overall is presented as relative breeding values with an average of 100 and a standard deviation of 4. It is important to keep in mind that numbers above 100 are desirable. A breeding value for ketosis of more than 100 indicates that ketosis will occur *less* in the daughter group. The effect of a breeding value of 104 on the offspring of a bull mated to an average cow is shown in table 6. The transmitting ability is calculated as one-half breeding value and indicates the actual effect on the offspring, since the sire and dam each pass on half their breeding value to the offspring. An overall breeding value of 104 for ketosis means that the offspring of the bull concerned are 1.5% less likely to have ketosis.

Table 6. Effect of relative breeding values for ketosis in offspring

Trait	*Relative breeding value*	*One-half breeding value (effect on offspring)*
Ketosis overall	104	-1.5%

Publication requirements

The publication requirement for all bulls is a minimum reliability of 25% for the breeding value of ketosis overall. For sampled AI bulls, the breeding value must be based on at least one descendant. For non-sampled AI bulls, the minimum requirement is 10 descendants.

Literature

OETZEL, G.R. Understanding The Impact of Subclinical Ketosis. Department of Animal Science, New York State College of Agriculture and Life Sciences. 2012

VAN DER DRIFT, S.G.A.; VAN HULZEN, K.J.E.; TEWELDEMEDHN, T.G.; JORRITSMA, R.; NIELEN, M.; HEUVEN, H. Genetic and Nongenetic Variation in Plasma and Milk β-hydroxybutyrate and Milk Acetone Concentrations of Early-Lactation Dairy Cows. Journal of Dairy Science. 2012

VAN DER DRIFT, S.G.A. Ketosis In Dairy Cows: Etiologic Factors, Monitoring, Treatment. 2013.

WELLER, D. Associations Between Canadian Holstein Dairy Cattle Health and Production Traits. 2013.