Statistical Indicators

E-8

Breeding Value Estimation for Conformation Traits

▪ Introduction

In 1981 the herdbook CRV introduced the herd classification system. All lactating heifers of herds enrolled in this system are regularly scored for conformation. In 1991, 1996, 1999, 2000, 2004 and 2008 the standard traits for conformation were adapted. These traits are standard for the European Holstein Herdbooks. Heifers are evaluated according to three standards: the Black&White (Z), the Red&White (R) or the Local (Y) standard.
Koepon Genetics Europe used this herd classification system with the standard traits from February 2002 to July 2014. As of August 2002 data collected by Koepon Genetics Europe is used in the Dutch conformation evaluation.
The herdbook FHRS uses their own standard: the FHRS-standard (F). Heifers classified after June 15th 2002 in the FHRS system are used as of August 2002 in the Dutch conformation evaluation.
In Flanders the herd classification system was introduced in 1991 by Vlaamse Rundveeteelt Vereniging vzw. Heifers are evaluated according to the Black&White or Red&White standard. Starting in November 2002 the Flemish and Dutch data is used in a joint conformation evaluation.

The classification systems above have enabled the routine estimation of breeding values for conformation. In October 1991 the animal model for conformation was introduced: the NL-animal model for type.
The NL-animal model for type results in cow and bull conformation indexes. The working of this model is described in chapter E-7 (about milk production).
The selection of the classification data, the use of pedigree information, the statistical model and the calculation of the reliability will be discussed.

▪ Selection of Classification Data

The NL-animal model for type uses all classifications of animals scored as heifer since 1981.
The requirements for a classification to be included in the animal model are:

1. the cow must be herd book registered.
2. the cow was a heifer at the time of the classification.
   Only heifer classifications are selected for breeding value estimation none or little selection has taken place. Only one classification will be used. If there are several classifications, the first classification of the animal is chosen.
3. the cow must have calved before 3 years of age.
4. the cow must have a known herd at the time of classification
5. the cow must be classified according to the Z, R, Y or F standard
6. the cow must be in the herd classification system or in an additional classification system. These systems are described elsewhere.
7. Linear traits are scored from 1 to 9
8. General characteristics are scored between 65 and 99 points. Heifers can have maximum 89 points for Overall conformation.

▪ Use of pedigree information

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

▪ Statistical Model

The statistical model that is used for the NL-animal model for type is:

$Y_{ijklmnopqr}$ = $RB_i + IK_j + AGE_k + LACT_l + AGE\_M_m + CAT\_S_n + het_o + rec_p + A_q + rest_r$

In which :
$Y_{ijklmnopqr}$: heifer classification of date * herd combination *i*, classifier * half-year * classification standard combination *j*, at age *k* of animal *q* in stage of lactation *l*;
RB_i : date * herd combination *i*;
IK_j : classifier * half-year * classification standard combination *j*;
AGE_k : age class *k* of animal *q* at the time of classification * 3 year;
$LACT_l$: stage of lactation class *l* of animal *q* at the time of classification * 3 year;
AGE_M_m : age class *m* of dam at the time birth of animal *q* * 6 year;
CAT_S_n : sire category * age class *n* of sire at the time of classification of animal *q* * 6 year;
Het_o : heterosis *m* of animal *o*;
Rec_p : recombinatie *n* of animal *o*;
A_q : additive genetic effect or breeding value of animal *o*;
$Rest_r$: residual-term *r* of $Y_{ijklmnpqr}$, which is not explained by the model.

The effects A and Rest are random effects, heterosis and recombination are co-variables and the other effects are included in the model as fixed effects.
The evaluations consist of the following linear traits and general characteristics:

Linear traits
- Stature
- Chest width
- Body depth
- Angularity
- Body condition
- Rump angle
- Rump width
- Rear leg rear view
- Rear leg side view
- Foot angle
- Locomotion
- Fore udder attachment
- Front teat placement
- Teat length
- Udder depth
- Rear udder height
- Udder support
- Rear teat placement

Overall traits
- Frame
- Dairy strength
- Udder
- Feet and legs
- Muscularity (only Y standard)
- Overall conformation

All traits mentioned above are scored by the classifier. If dairy strength is not scored, then dairy strength is derived from the linear traits: chest width, body depth, body condition and rump width. Dairy strength has a direct relationship with longevity. The mentioned linear traits are so-called optimum traits regarding the relationship with the percentage cows culled at the beginning of the third lactation. Every trait has an optimum for the weight in dairy strength that is a bit higher than the average score of 5 (on a scale of 1 to 9). This choice was made because of the wishes of the Dutch dairy farmers to breed a bit heavier cow with a bit more body condition than the current cows. The score for dairy strength is derived for all cows that have a score for chest width, body depth, body condition and rump width.
Over time changes in trait definitions occurred for several traits. When a trait definition changed, this has to be considered in the breeding values estimation, because we want to publish according to the latest definition.
In order to be able to use the scores of the trait according to old definition, the genetic correlation between old and present definition in the breeding value estimation is used.
There are also differences in trait definition between Flanders and the Netherlands. Four traits have a difference in trait definition: chest width, fore udder attachment, Frame and Feet & Legs. The data scored by Flemish classifiers before September 1 2002 are treated as a different trait in the evaluation. After September 1 2002 Flemish and Dutch classifiers score according to the same definition.
Besides trait definition changes, introduction of new traits in the classification system occurs as well. Animals which have been scored pre to the introduction of the new trait do not have a score for this trait. The consequence will be that cows without a score and sires with few or no daughters scored, will get a breeding value with a low reliability for this trait. To avoid this a multiple trait evaluation is used. The new trait will have a reasonable genetic correlation with traits already present in the classification system. In that case these genetic correlations will be used in the breeding value estimation. Therefore animals without a score for this new trait will still get a reliable breeding value for this trait.

A multiple trait genetic evaluation is used to accommodate both of the above situations (change in trait definition and new trait). There are 3 trait groups, frame traits, udder traits and feet & leg traits. Correlations are used within trait groups. Table 1 shows the correlations for the trait group frame, table 2 for the udder traits and table 3 for the feet & legs traits.

Table 1. Genetic correlations between body traits.

	STA	CWI	BDE	ANG	BCS	RAN	RWI	DS	MU	MUL	CW2	BD2	BD3	AN2	RW2	V-CW
Stature																
Chest width	0.34															
Body depth	0.56	0.66														
Angularity	0.51	0.41	0.79													
Body Condition	0.00	0.71	0.15	-0.05												
Rump angle	0.23	0.02	0.02	0.11	0.05											
Rump width	0.38	0.34	0.39	0.30	0.00	0.05										
Dairy strength	0.39	0.68	0.44	0.43	0.64	0.19	0.18									
Muscularity	0.11	0.67	0.20	-0.15	0.81	0.07	0.23	0.57								
Muscularity linear	0.06	0.65	0.15	-0.23	0.81	0.05	0.18	0.59	0.90							
Chest width 2	-0.25	-0.81	-0.50	-0.08	-0.71	0.01	-0.33	-0.59	-0.82	-0.84						
Body depth 2	0.36	0.63	0.83	0.53	0.17	-0.01	0.41	0.32	0.34	0.29	-0.61					
Body depth 3	0.26	0.57	0.77	0.48	0.20	-0.04	0.33	0.36	0.38	0.34	-0.60	0.87				
Angularity 2	0.38	-0.21	0.47	0.63	-0.69	-0.05	0.14	-0.22	-0.62	-0.66	0.36	0.32	0.28			
Rump width 2	0.37	0.46	0.52	0.24	0.18	0.09	0.72	0.13	0.44	0.36	-0.52	0.56	0.51	0.00		
VRV chest width	0.61	0.78	0.70	0.38	0.41	0.06	0.52	0.49	0.51	0.50	-0.74	0.64	0.52	0.02	0.62	
Dairy Strength derived	0.33	0.54	0.24	0.08	0.66	0.16	-0.01	0.81	0.68	0.71	-0.63	0.25	0.32	-0.37	0.05	0.39

The upper left most corner of the table within the black lines are the traits that are published. The other traits are correlated traits. The traits with their time frame are:

Current traits
Stature (1980)
Chest width (1996)
Body depth (1996)
Angularity (2008)
Body condition (1998)
Rump angle (1980)
Rump width (1991)
Dairy strength (2007)
Muscularity (only MRIJ, 1980)
Dairy strength derived (1998)

Historical traits
Muscularity linear (scored from 1980 to 1996 for all animals, for Red and White to 2004)
Chest width 2 (scored from 1986 to 1988)
Body depth 2 (scored from 1991 to 1996)
Body depth 3 (scored from 1980 to 1991)
Angularity 2 (scored from 1996 to 2008)
Rump width 2 (scored from 1980 to 1991)
VRV Chest width = Chest width scored in Flanders (scored from 1991 to 2002)

Table 2. Genetic correlations between udder traits.

	FUA	FTP	FTL	UDE	RUH	USU	RTP	U	FU2	RH2
Fore udder attachment										
Front teat placement	0.32									
Teat length	-0.02	-0.19								
Udder depth	0.77	0.24	-0.13							
Rear udder height	0.40	0.04	0.04	0.42						
Udder support	0.06	0.33	-0.09	0.16	0.30					
Rear teat placement	0.12	0.58	-0.21	0.11	0.18	0.80				
Udder	0.81	0.50	-0.12	0.81	0.60	0.36	0.38			
Fore udder attachment 2	0.87	0.47	-0.17	0.78	0.32	0.24	0.32	0.82		
Rear udder height 2	0.34	0.26	-0.01	0.34	0.87	0.42	0.38	0.62	0.31	
VRV fore udder attachment	0.84	0.49	-0.15	0.61	0.32	0.24	0.35	0.74	0.86	0.33

The upper left most corner of the table within the black lines are the traits that are published. The other traits are correlated traits. The traits with their time frame are:

Current traits
Fore udder attachment (1996)
Front teat placement (1980)
Teat length (1980)
Udder depth (1980)
Rear udder height (1996)
Median suspensory (1980)
Rear teat placement (2000)
Udder (1980)

Historical traits
Fore udder attachment 2 (1980-1996)
Rear udder height 2 (1980-1996)
Fore udder attachment in Flanders (1991-2002)

Table 3. Genetic correlations between the feet & legs traits.

	RLR	RLS	FAN	LOC	F&L	FA2
Rear leg rear view						
Rear leg side view	-0.22					
Foot angle	0.31	-0.72				
Locomotion	0.83	-0.24	0.31			
Feet & legs	0.80	-0.38	0.42	0.92		
Foot angle 2	0.53	-0.69	0.87	0.54	0.63	
VRV Feet & Legs	0.71	-0.69	0.72	0.77	0.84	0.84

The upper left most corner of the table within the black lines are the traits that are published. The other traits are correlated traits. The traits with their time frame are:

Current traits
Rear leg rear view (1998)
Rear leg side view (1980)
Foot angle (1997)
Locomotion (2002)
Feet & Legs (1980)

Historical traits
Foot angle 2 (1991-1997)
Feet & legs in Flanders (1991-2002)

In total, breeding values for 24 traits are estimated. For the estimation of the breeding values for conformation, the classification data are corrected in two ways: by means of an adjustment for variation of classifications per classifier and by means of a model.

Adjustment for Variation per Classifier
Before classifications are used in the model, an adjustment is made for the variation of these classifications with respect to the classifiers. This adjustment is made per classification standard for all the classifications that a classifier has made in a six month period. The goal

is to standardise the variation of the classifications, because some classifiers have more variation in their classification of cows than others and this variation may change during time. The formula for standardisation of variation is:

$S^* = (S - M_{in})*(STD_{tot}/STD_{in})+M_{in}$

In which:

S^*	= adjusted score
S	= score for trait given by classifier
STD_{tot}	= variation of all classifications per trait per six months per classification-standard
STD_{in}	= variation of all classifications of one classifier per six months per classification-standard
M_{in}	= mean score for trait given by the classifier

The effects in the Model

The effects in the model are:

1. date * herd
2. classifier * half a year * classification standard
3. age at classification * 3 year
4. lactation stage at classification * 3 year
5. age of dam * 6 year
6. sire category * age of sire * 6 year
7. heterosis
8. recombination
9. additive genetic effect or breeding value.

*Date * herd*

Each date * herd combination represents a new level in the model. This means that all the classifications on one day in one herd are compared with each other. Animals that are classified on the same day but by different classifiers or on different classification standards will be compared with each other in the same date * herd class in the genetic evaluation.

*Classifier * half year * classification standard*

This effect makes it possible to compare animals in one herd classified on a different classification standard. The differences between these animals are adjusted for the differences made by the classifier between two classification standards in half a year. This effect also accounts for the differences made by two classifiers that classify cows in one herd at one day.

The minimum number of observations per class is 100. If there are less than 100 observations per classification standard, the records are successively merged within classifier and year of classification, across classifiers and within half a year of classification, across classifiers and within year of classification and possibly across classifiers and across years of classification. A year of classification runs from September to August because adaptations to the classification sheet are in the past mainly made in September.

*Age at Classification * 3 year*

Research shows that the age at classification has an effect on the classification. This has to be included in the model. 18 Age categories are distinguished, from which category 1 is adjusting classifications to the age of 24 month and younger. Category 2 to 17 incl. adjusts to the age of 25 to 40 months incl. at classification. In category 18 all the cows are included that are 41 months old or older. The age classes are divided in periods of 3 years. This is to take in account the changing of how classifiers judge the type depending on age of the cow.

*Lactation Stage at Classification * 3 year*
Research shows that, besides age, also the lactation stage at classification has an effect on the classification and is therefore included in the model. 13 Lactation categories are distinguished, one category for each month in lactation. In category 13 all the cows are included that have been in lactation for 13 months or more at the moment of classification. The lactation stage classes are divided in periods of 3 years. This is to take in account the changing of how classifiers judge the type depending on the lactation stage of the cow.

*age of dam * 6 year*
Age of dam at birth of classified cow, divided in whole years. Cows of 7 years and older are grouped together. Dams with an unknown birthdate are grouped in a separate class. With this division, a distinction is made between cows born from heifers, which are not fully matured and give lighter calves, and older cows, which are mature and give heavier calves. Calves born from heifers can be less developed when they are classified. The age of dam classes are divided in periods of 6 years. This is to take in account the changing of how classifiers judge the type depending on the age of the dam at the moment of birth of the classified cow.

*sire category * age of sire * 6 year*
Sire category * age class *n* of sire of animal *q* at the time of classification. There are four sire categories: a) first crop daughters of A-category bulls (nationally tested AI sires), b) second crop daughters of A-category bulls, c) second crop daughters of B-category bulls (internationally tested AI sires), and d) daughters of C-category bulls (not AI tested sires) + rest. Age of sire is divided in 14 classes (2, 3, 4, …, 14, ≥15 year). With this division per sire category, a distinction is made between different type of sires and how these sires are used, for example first crop bulls are used more randomly used and second crop bulls are used more selective. The sire category * age of sire classes are divided in periods of 6 years. This is to take in account the changing of how classifiers judge the type depending on the sire category * age of the sire at the moment of classification of the classified cow.

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 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 or Breeding Value
Each trait has its own heritability in the NL-animal model for type. These heritabilities are shown in table 4. Principles of breeding value estimation are explained in part E-7.

Table 4. Heritabilities (h^2) used in the NL-animal model for type.

	Linear traits	h^2		Linear traits	h^2
STA	Stature	0.52	FAN	Foot angle	0.14
CWI	Chest width	0.24	LOC	Locomotion	0.14
BDE	Body depth	0.31	FUA	Fore udder attachment	0.27
ANG	Angularity	0.11	FTP	Front teat placement	0.38
BCS	Body condition score	0.30	FTL	Teat length	0.38
RAN	Rump angle	0.34	UDE	Udder depth	0.38
RWI	Rump width	0.40	RUH	Rear udder height	0.23
RLR	Rear leg rear view	0.15	USU	Udder support	0.23
RLS	Rear leg side view	0.23	RTP	Rear teat placement	0.32

▪ Composites: Calculation of the Breeding Values for overall traits

The breeding values for overall traits are calculated from breeding values of the linear traits. These breeding values for the overall traits are called 'composites'. The calculation, that is in place since April 2015, is applied on the breeding values for the overall traits frame, dairy strength, udder and feet and legs. The breeding value for muscularity is still based on the score of the classifier. Overall conformation is based on the overall traits, and has not been changed in April 2015.

Advantages of using composites are:

- Transparency: It can be checked why a bull is better suited or less suited for a breeding goal. By re-calculating the composite it provides insight on what linear traits a bull earns points and on what parts he loses points.
- International conversion improves: Linear traits have higher correlations between countries than the overall traits. By calculating the overall traits based on the converted linear traits, the composites of bulls with foreign breeding values have a higher reliability.
- Change in breeding goal or trait definition allows a quick change: When the breeding goal changes, for all animals (young and old) composites can be calculated. There is no waiting period until enough scored animals based on the change in breeding goal are available.

When the composites were developed, the goal was to have less emphasis on stature, rear legs do not have to get steeper and rear teat placement should not get more narrow compared to the situation in April 2015.

The breeding goal for the four composites described in words, is as follows:
Frame: A cow that is in her whole body a bit bigger than the current cow. This is a cow that is wider in the front, with more capacity, and a more sloped and wider rump. Stature is not taken into account.
Dairy strength: A robust cow with more capacity throughout her whole body, with especially more angularity and more body condition. Stature is not taken into account.
Udder: A cow with a stronger attached and more shallow udder, with a higher rear udder and stronger udder support, of which both front and rear teats do not have to be placed more narrow and rear teats can be placed even wider, and teats do not have to be longer or shorter.
Feet and Legs: A cow that is standing more parallel on her rear legs and has a better locomotion. Rear legs can become a bit more curved and the foot angle can become more steep.
In 2018 a separate composite formula was established for the dual purpose breeds.

The formulas to calculate the composites for milk goal are:

Frame: $0.34 \times (BV_{CWI}^{*} - 100) + 0.34 \times (BV_{BDE}^{*} - 100) + 0.52 \times (BV_{RAN}^{*} - 100) + 0.52 \times (BV_{RWI}^{*} - 100) + 100$

Dairy Strength: $-0.026 \times (BV_{CWI}^{**} - 100)^2 - 0.026 \times (BV_{BDE}^{**} - 100)^2 + 0.63 \times (BV_{ANG} - 100) + 0.63 \times (BV_{BCS} - 100) + 0.21 \times (BV_{RWI} - 100) + 101$

Udder: $0.37 \times (BV_{FUA} - 100) + 0.09 \times (BV_{FTP} - 100) - 0.0075 \times (BV_{FTL}^{**} - 100)^2 + 0.37 \times (BV_{UDE} - 100) + 0.37 \times (BV_{RUH} - 100) + 0.28 \times (BV_{USU} - 100) - 0.28 \times (BV_{RTP}^{***} - 100) + 100$

F&L: $0.23 \times (BV_{RLR} - 100) - 0.0325 \times (BV_{RLS}^{**} - 102)^2 + 0.16 \times (BV_{FAN} - 100) + 0.78 \times (BV_{LOC} - 100) + 100$

Where:
* Breeding values of 104 and higher are maximised to 104 for CWI, BDE and RWI; breeding values of 108 and higher are maximised to 108 for RAN
** Breeding values are weighted with a quadratic optimum, optimum for CWI, BDE, FTL is 100 and optimum for RLS is 102, where breeding values differing more than 12 points from the optimum are also set to a difference of 12 points
*** Breeding values of 92 and lower are minimised to 92

Figure 1 shows the contribution in the composite when the linear trait is weighted linear, is maximised, is minimised, or is weighted as an optimum.

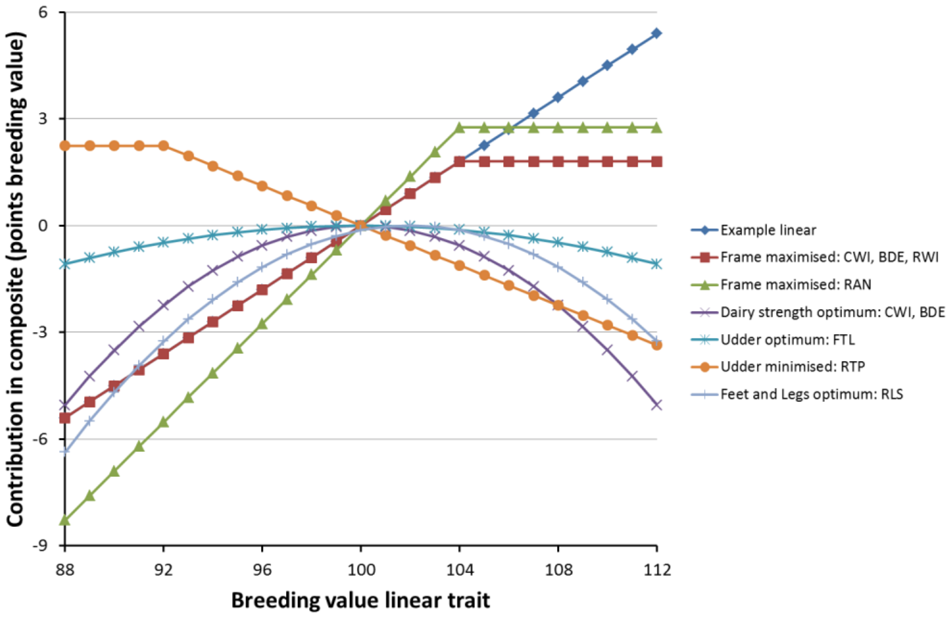

Figure 1. Contribution in the composite for linear traits which are weighted linear, are maximised, are minimised, or weighted as a quadratic optimum.

Above formulas can be used to re-calculate the composite, and all breeding values should have the same base. In Table 5 the relative weights are given for the linear traits in each composite. This shows the importance of a linear trait in a certain composite.

Table 5. Relative weight of linear traits in milk goal composites for frame, dairy strength, udder and feet & legs

Frame	weight	Dairy strength	weight	Udder	weight	Feet and Legs	weight
STA		STA		FUA	20%	RLR	15%
CWI	20%	CWI	15%	FTP	5%	RLS	25%
BDE	20%	BDE	15%	FTL	5%	FAN	10%
ANG		ANG	30%	UDE	20%	LOC	50%
BCS		BCS	30%	RUH	20%		
RAN	30%	RAN		USU	15%		
RWI	30%	RWI	10%	RTP	-15%		

The formula for the dual purpose composites are:

Frame: 0.30 x (BV_{STA} – 100) + 0.40 x (BV_{CWI}* – 100) + 0.40 x (BV_{BDE}* – 100) + 0.40 x (BV_{RAN}* – 100) + 0.50 x (BV_{RWI}* – 100) + 100

Dairy Strength: $-0.0258 \text{ x } (BV_{CWI}{}^{**} – 104)^2 – 0.0258 \text{ x } (BV_{BDE}{}^{**} – 104)^2 + 0.31 \text{ x } (BV_{ANG} – 100) + 0.42 \text{ x } (BV_{BCS} – 100) + 0.31 \text{ x } (BV_{RWI} – 100) + + 0.41 \text{ x } (BV_{MUSC} – 100) + 101$

Udder: $0.27 \text{ x } (BV_{FUA} – 100) + 0.27 \text{ x } (BV_{FTP} – 100) – 0.0075 \text{ x } (BV_{FTL}{}^{**} – 100)^2 + 0.36 \text{ x } (BV_{UDE} – 100) + 0.36 \text{ x } (BV_{RUH} – 100) + 0.36 \text{ x } (BV_{USU} – 100) – 0.075 \text{ x } (BV_{RTP}{}^{**} – 104) + 100$

F&L: $0.32 \text{ x } (BV_{RLR} – 100) – 0.0267 \text{ x } (BV_{RLS}{}^{**} – 102)^2 + 0.16 \text{ x } (BV_{FAN} – 100) + 0.78 \text{ x } (BV_{LOC} – 100) + 100$

Where:
* Breeding values of 104 and higher are maximised to 104 for BDE and RWI; ; breeding values of 106 and higher are maximised to 106 for CWI breeding values of 108 and higher are maximised to 108 for RAN
** Breeding values are weighted with a quadratic optimum, optimum for RTP is 100, optimum for CWI, BDE, RTP is 104 and optimum for RLS is 102, where breeding values differing more than 12 points from the optimum are also set to a difference of 12 points

In table 6 the relative weihgts are sown for the linear traits in the composites for the dual purpose.

Table 6. Relative weight of linear traits in dual purpose composites for frame, dairy strength, udder and feet & legs

Frame	weight	Dairy strength	weight	Udder	weight	Feet and Legs	weight
STA	15%	STA		FUA	15%	RLR	20%
CWI	20%	CWI	15%	FTP	15%	RLS	20%
BDE	20%	BDE	15%	FTL	5%	FAN	10%
ANG		ANG	15%	UDE	20%	LOC	50%
BCS		BCS	20%	RUH	20%		
RAN	20%	RAN		USU	20%		
RWI	35%	RWI	15%	RTP	-5%		
MUSC			20%				

▪ Calculation of the Breeding Value Overall conformation

The breeding value for overall conformation of an animal is a composite of frame, dairy strength, udder, feet and legs and muscularity. The weights of these traits are in Table 7.

Table 7. Weight factors for the different traits included in overall conformation per base of publication.

	Milk goal Black	*Milk goal Red*	*Dual purpose/ Belgian Blue*
Frame	20%	20%	15%
Dairy strength	10%	10%	10%
Udder	35%	35%	30%
Feet and legs	35%	35%	30%
Muscularity	0%	0%	15%

The formulas to calculate Overall conformation are:

(Black/Red): $0.30 \times (BV_{frame} - 100) + 0.15 \times (BV_{dairy\ strength} - 100) + 0.53 \times (BV_{udder} - 100) + 0.53 \times (BV_{feet\ and\ legs} - 100) + 100$

(Dual purpose): $0.23 \times (BV_{frame} - 100) + 0.15 \times (BV_{dairy\ strength} - 100) + 0.45 \times (BV_{udder} - 100) + 0.45 \times (BV_{feet\ and\ legs} - 100) + 0.23 \times (BV_{muscularity} - 100) + 100$

The composite for overall conformation is calculated using the composites of the overall traits, and the used weight factors result in a relative breeding value with mean of 100 and a standard deviation of 4 points.

▪ Reliability

For the calculation of the reliabilities, heritabilities from Table 4 and genetic correlations between traits from Table 1 to 3 are used. For each trait a reliability is calculated. The published reliability is the reliability of overall conformation, and based on the reliabilities of the composites and the weight factors in Table 6.

▪ Base

Breeding values for conformation traits are published based on the 2015-base. Cows born in 2010 determine the base of 2015. There are four different bases: Milk goal Black, Milk goal Red, Dual purpose and Belgian Blue. The definitions of these bases are as follows:

Milk goal Black (Z)
Herdbook-registered animals born in 2010 with at least 87.5% HF-blood and up to 12.5% FH-blood and hair colour black pied, with an official classification.

Milk goal Red (R)
Herdbook-registered animals born in 2010 with at least 87.5% HF-blood and up to 12.5% MRY-blood and hair colour red pied, with an official classification.

Dual purpose (D)
Herdbook-registered animals born in 2010 with at least 75% MRIJ-blood and 25% or less HF blood, with an official classification.

Belgian Blue (B)
The Belgian Blue base is determined by the animals that determine the Dual purpose base.

The distribution of breeding values is determined by the Milk goal Black 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 8. The base differences of the Dual purpose base also apply to the Belgian Blue base.

Table 8. Base differences for conformation traits

Trait	**Z → R**	**Z → D**	**R → D**
Stature	2	12	10
Chest width	0	-7	-7
Body depth	1	8	7
Angularity	2	16	14
Body condition score	-3	-13	-10
Rump angle	-1	-8	-7
Rump width	1	0	-1
Rear leg rear view	0	0	0
Rear leg side view	1	2	1
Foot angle	0	-3	-3
Locomotion	0	1	1
Fore udder attachment	1	10	9
Fore teat placement	0	8	8
Fore teat length	2	-2	-4
Udder depth	1	9	8
Rear udder height	2	17	15
Udder support	2	9	7
Rear teat placement	2	8	6
Frame[1]	0	-7	-7
Dairy strength[1]	0	0	1
Udder[1]	1	14	13
Feet and Legs[1]	0	0	0
Muscularity[2]	-	-	-
Overall conformation[1]	1	5	5

[1] For the conversion of these traits the underlying linear traits are converted, and then the composite formula is applied. The given base differences are an indication and apply to a whole population.

[2] Musculairity overall is only published for the Dual purpose base. When breeding values of an animal are converted to the dual purpose base, the breeding value for muscularity overall can be derived with the following formula:
$BV_{musculairty} = 0.52 + 0.037 \times (BV_{STA} - 100) + 0.1646 \times (BV_{CWI} - 100) + 0.6356 \times (BV_{BDE} - 100) - 0.6321 \times (BV_{ANG} - 100) + 0.4878 \times (BV_{BCS} - 100) + 0.0820 \times (BV_{RAN} - 100) + 0.0856 \times (BV_{RWI} - 100) + 100$

▪ Publication requirements

Breeding values of an AI bull are published in case the reliability is at least 25 percent and the breeding values is based on at least one offspring.
Bulls are considered AI bulls when they have an AI code and an owner who is not registered as a farmer. A non-AI bull will be published as soon as they have ten daughters in the breeding value estimation and the reliability at least 25 percent is for overall conformation.

▪ Interpretation breeding values linear traits

Table 9 describes the biological interpretation of the breeding values for the linear traits when used on an average cow with breeding value 100. For chest width for example, a breeding value higher than 100 will on average result in a wider chest, and a breeding value lower than 100 will on average result in a narrower chest. In the table the interpretation is given for all 18 linear traits.

Table 9. Biological interpretation of breeding values for linear traits lower and higher than 100.

Trait	Lower than 100	Higher than 100
Stature	short	tall
Chest width	narrow	wide
Body depth	shallow	deep
Angularity	closed	open
Body condition score	skinny	fat
Rump angle	high pins	sloped pins
Rump width	narrow	wide
Rear leg rear view	hocked-in	straight
Rear leg side view	straight	curved
Foot angle	low	steep
Locomotion	weak	strong
Fore udder attachment	weak	strong
Fore teat placement	wide	narrow
Fore teat length	short	long
Udder depth	deep	shallow
Rear udder height	low	high
Udder support	weak	strong
Rear teat placement	wide	narrow

▪ Literature

Koenen, E.P.C., R.F. Veerkamp, P. Dobbelaar and G. De Jong, 2001. Genetic analysis of body condition score of lactating Dutch Holstein and Red-and-White heifers. Journal of Dairy Science, mei 2001, page 1265.
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