Breeding for resilience in the Netherlands and Flanders

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Abstract

Dairy cows could face several environmental disturbances during a lactation like weather conditions or changes in roughage quality, resulting in reduced functioning. Cows which are minimally affected by disturbances and/or quickly recover are the preferred cows. Reduced functioning of dairy cows is measured as the difference in daily milk yield and the expected milk yield for that day. This is called deviation. The expected daily milk yield is estimated with polynomial quantile regression based on all milkings of a cow during a lactation. Based on the deviations, two resilience traits are calculated: stability and recovery. Stability is the natural logarithm of the variance (LnVar) from all deviations during a lactation, recovery is the autocorrelation (Rauto) between all deviations during a lactation. A lower LnVar indicates less affection by disturbances, thus more stability, a lower Rauto indicates quicker recovery. Breeding values are estimated for stability and recovery for lactation 1, lactation 2 and lactation 3 and higher (3+). Heritability (h^2) is 0.09, 0.06 and 0.09 for stability and 0.07, 0.04 and 0.04 for recovery for respectively lactation 1, 2 and 3+. Genetic correlations between different parities for stability ranges from 0.91 to 0.98 and for recovery it ranges from 0.84 to 1.00. Overall breeding values for stability and recovery are calculated based on traits in lactation 1, 2 and 3+. An overall index for resilience is calculated based on the overall breeding values for stability and recovery. Breeding on resilience results in cows that are less affected by environmental disturbances and recover quicker. The overall index and the two overall breeding values are the traits that are published in the Netherlands and Flanders since April 2024.

Key words: resilience, milk yield, variance, autocorrelation, automatic milking system, dairy cow

Introduction

Focus in dairy breeding is more and more on health. There are numerous health traits where breeders can breed for: fertility, udder health, claw health, reproduction disorders and metabolic disorders.

These health traits are all aiming at one specific health factor. However, dairy farmers are looking for cows with a good general health and which can cope with different circumstances and changes in the environment. This is called resilience. Resilience is the ability to be minimally affected by disturbances and/or to recover quickly when affected (Colditz and Hine, 2016).

Previous research has shown that fluctuations in milk yield are heritable and can be used as resilience indicator (Elgersma et al., 2018), and different resilience traits can be made from the fluctuations in milk yield (Poppe et al., 2020).

Since 2010, records on milk yield of individual cows during their visit in the automatic milking system (AMS) or milking parlour with electronic milk measure device (EMM) are automatically uploaded to the database of CRV when the Dutch or Flemish dairy farmer is willing to share the data. This makes it possible to estimate the lactation curve of the cow and to calculate fluctuations in milk yield based on 24h milk yield of the cow.

The availability of the data on individual milk yield observations and the previous research on resilience based on fluctuations of milk yield (Poppe et al., 2020), made it possible for CRV to estimate and publish breeding values for resilience in the Netherlands and Flanders since April 2024.

Materials and Methods

Data for breeding value estimation

Individual milk yield data is available for the genetic evaluation from more than 6,850 Dutch and Flemish dairy farms. These farms are milking their cows with an AMS or milk parlour with EMM. Each week, around 14 million milk yield observations are added to the database.

Based on milk yield and milk interval with the previous milk event of the cow, the 24h milk production of the cow is calculated up to 350 days in lactation. If the milk interval with the previous milk event is more than 24 hours, the 24h milk production is not calculated for that day, and also not for the day before.

Special attention is needed to uncompleted milk events, because the milk yield will be less than expected based on milk interval, while the next milk event, if completed, will result in a higher milk yield than expected based on milk interval because the extra milk from the uncompleted milk event is still in the udder of the cow. Therefore, the milk yield of both milk events is summed up and the milk interval is calculated as the time between the milk event before and after the uncompleted milk event.

If the cow has at least 50 days with a known 24h milk yield between day 11 and 340 in lactation, and if at least 70 percent of the days between the first and last day with a known 24h milk yield has a known 24h milk yield, an optimal production curve will be estimated for the cow in that lactation. This optimal production curve will be calculated using a fourth order polynomial quantile regression (Koenker, 2005). A 0.7 quantile is used, what makes the assumption that the realized production of the cow (24h milk yields during the lactation) is already disturbed by environmental factors.

From day 11 to day 340 in lactation, for each day the deviation (realized production – optimal production) will be calculated. Two resilience indicators will be calculated based on the deviations: Rauto and LnVar. The Rauto is a lag-1 autocorrelation, and LnVar is the natural logarithm of the variance.

The Rauto is a measure of how quickly a cow can recover from a drop in milk production, so the trait is called recovery. The LnVar is a measure of how many drops in milk yield the cow has during a lactation, so the trait is called stability.

Data from all parities is used. In the April 2024 breeding value estimation, the number of individual milk events was 5,056,750,621 which can be reduced to 5,967,719 lactations. After some selection steps as described in E-chapter Resilience (CRV u.a., 2024), 2,818,469 lactations from cows milked by an AMS and 869,526 lactations from cows milked in a milking parlour with EMM are left. This data is from 6,857 different herds and 1,338,368 animals.

Parameters

Parameter estimation was based on 357,531 lactations from 172,981 cows with 149,275 lactations belonging to parity 1 (104,878 from AMS, 44,397 from EMM), 103,552 belonging to parity 2 (78,657 from AMS, 24,895 from EMM) and 104,704 belonging to parity 3 and higher (81,970 from AMS, 22,734 from EMM). All cows were at least 87.5% Holstein. Parameters were estimated using an animal model.

Model

The statistical model used for resilience based on fluctuations in daily milk yield is:

$$Y_{ijklmnopqrst} = HYS_i + DIL_j + AFC_k + PAR_l + DM_m + KGM_n + HET_o + REC_p + INB_q + A_r + PME_s + Rest_t$$

In which:

Y	observation on resilience on heifers (parity 1), young cows (parity 2) and cows (parity 3+);
HYS	herd x year x season of first calving;
DIL	length of lactation;
AFC	age at first calving;
PAR	parity number;
DM	difference in milk yield compared to herd mean;
KGM	average daily milk yield during the lactation;
HET	heterosis effect;
REC	recombination effect;
INB	inbreeding effect;
A	additive genetic effect;
PME	permanent environmental effect;
Rest	residual term of that which is not explained by the model of Y.

The effects A, PME and Rest are random, the effects HET, REC and INB are covariables, the other effects are fixed. AFC is only added to the model for parity 1 and parity 2, PAR is only added to the model for parity 3+.

DIL consist of seven classes, divided into periods of three years. The first class is between 50 and 90 days, where the number of days reflects the amount of days with a known 24h milk yield during the lactation. Each class consist of 40 days, and the seventh class is from 290 days and higher with data.

The variance of the deviation in milk yield is sensitive for the level of milk production of the cow. High yielding cows have a higher variance by nature. Therefore, DM and KGM are added to the model to correct for the level of milk production of the cow and the herd.

Results & Discussion

The descriptive statistics for recovery and stability are given in Table 1. These numbers are based on the April 2024 breeding value estimation, and data selection was done as described in E-47 (CRV u.a., 2024). The descriptive statistics are based on cows milked by AMS.

Table 1: Descriptive statistics (mean, standard deviation (sd), minimum (min.) and maximum (max.)) of the autocorrelation (recovery) and LnVar (stability) for parity 1 (p.1), parity 2 (p.2) and parity 3+ (p.3) based on cows milked by AMS.

Trait	Mean	SD	min.	max.
autocorrelation p.1	0.56	0.20	-0.21	0.98
autocorrelation p.2	0.56	0.19	-0.26	0.99
autocorrelation p.3	0.56	0.19	-0.32	0.98
LnVar p.1	1.57	0.67	-1.01	3.95
LnVar p.2	1.85	0.69	-0.74	4.30
LnVar p.3	2.06	0.70	-0.98	4.64

The mean observation for autocorrelation is equal over the different parities, while for LnVar there is a clear increase over the lactations. Higher values for autocorrelation and LnVar indicates less resilience, so younger cows have better observations on LnVar than the older cows (1.57 *vs.* 2.06).

When a cow has a drop in daily milk yield, the deviation between realized and predicted milk yield becomes large and negative. Many large deviations during the lactation will result in a high LnVar (poor stability), and many large negative deviations in a row will result in a high autocorrelation (long recovery). So, lower values for LnVar and autocorrelation indicates better recovery and stability because the realized daily milk yield is close to the predicted milk yield.

Genetic parameters

Table 2 shows heritabilities of the resilience traits. Table 3 shows the genetic correlations between the same traits, but measured on two different milking systems. Table 4 shows genetic correlations over the different parities within the same traits measured on cows milked by AMS.

The heritabilities in table 2 shows that stability has a higher heritability compared to recovery. Traits retrieved from AMS data have higher heritability compared to traits retrieved from EMM data.

Table 2: Heritabilities of recovery and stability in parity 1 (p.1), parity (p.2) and parity 3+ (p.3) for AMS and EMM observations.

Trait	AMS	EMM
recovery p.1	0.07	0.04
recovery p.2	0.04	0.03
recovery p.3	0.04	0.02
stability p.1	0.09	0.05
stability p.2	0.06	0.05
stability p.3	0.09	0.04

An AMS will measure all milk events of the cow, even when the cow is sick and treated with, for example, antibiotics. An EMM will not measure the milk yield of a cow when the cow is treated with antibiotics, because this milk is not going into the milk tank. Cows are normally only treated with antibiotics when they are ill, so affected by an environmental disturbance. This makes that in the EMM dataset data is missing that will bring most variance in the resilience traits. As a result, traits based on EMM data have lower heritabilities.

Table 3: Genetic correlations for the resilience traits in parity 1 (p.1), parity (p.2) and parity 3+ (p.3) between AMS and EMM observations.

	recovery	stability
p.1	0.76	0.90
p.2	0.63	0.88
p.3	0.35	0.91

The difference between resilience based on AMS or EMM observations is visible in the genetic correlations for recovery. In parity 1, the genetic correlations between recovery for cows milked by AMS or milked by EMM is 0.76. In parity 2, this genetic correlation declined to 0.63. In parity 3+ it is even lower, 0.35. Lower genetic correlations are found for the later parities because there will be more use of antibiotics for older cows.

Table 4: Genetic correlations for recovery and stability between parity 1 (p.1), parity (p.2) and parity 3+ (p.3) for AMS and EMM observations.

	recovery	stability
p.1 – p.2	0.98	0.98
p.1 – p.3	0.84	0.91
p.2 – p.3	1.00	0.98

The genetic correlations between different parities of the same trait are all high. The lowest correlations are found for the parities that are most apart from each other, namely parity 1 and parity 3+. For recovery, this genetic correlation is 0.84, and for stability it is 0.91. These genetic correlations indicate less reranking of animals between the different traits.

Health

The aim of developing breeding values for resilience is to captures all health factors in one trait. Table 5 shows the genetic correlations with other health traits and production, since production is still one of the most important traits in dairy breeding. The resilience traits in table 5 are overall breeding values, and are composed of parity 1, parity 2 and parity 2+ with a weight of respectively 0.41, 0.33 and 0.26.

Table 5: Genetic correlations for the overall resilience traits with production and other health traits.

trait	recovery	stability
milk production	-0.14	-0.36
fertility	0.08	0.31
ketosis	0.16	0.49
longevity	-0.06	0.33
metabolic disorders	0.14	0.48
claw health	-0.03	0.14
reproduction disorders	0.06	0.15
udder health	0.22	0.50

The model is correcting for the level of milk yield of the cow on a phenotypic level. Despite this correction, there is still a negative genetic correlation between resilience and milk production. High yielding cows are less resilient.

The health traits have positive genetic correlations with resilience. Only recovery has slightly negative correlations with longevity and claw health, but they are not significant different from zero. Highest genetic correlations between resilience and health traits are found for stability with fertility (0.31), ketosis (0.49), longevity (0.33), metabolic disorders (0.48) and udder health (0.50).

Resilience on farm

The performances of dairy cows with breeding values for resilience were analyzed to check the validity of the breeding values. For recovery, the time it takes to recover from a drop in milk production was counted during a lactation. For stability, the number of drops in milking production during a lactation were counted.

This was done for cows with breeding values two standard deviations below average (low resilience, EBV 92), cows with a mean breeding value (average resilience, EBV 100) and cows with breeding values two standard deviations above average (good resilience, EBV 108). The results of this check are shown in table 6.

Table 6: On farm performances for cows with low (EBV 92), average (EBV 100) or high (EBV 108) breeding values for recovery and stability.

		EBV		
trait	unit	92	100	108
recovery	days to recover	14.0	10.9	7.0
stability	number of drops	4.8	3.8	2.4

Cows with high breeding values for recovery recover two times faster than cows with low breeding values, 7.0 *vs.* 14.0 days.

For stability is the same pattern visible. Cows with high breeding for stability have half of the number of drops in milk production compared to cows with lows breeding values, respectively 2.4 *vs.* 4.8.

Conclusions

Fluctuations in milk yield, retrieved from AMS and EMM systems, can be used as indicator to derive resilience traits. In the Netherlands and Flanders, two resilience traits are derived based on individual milk event data: recovery and stability.

Heritabilities are low for both recovery and stability, ranging from 0.04 to 0.09. The heritabilities for the same traits based on EMM data are slightly lower. Between AMS and EMM data, recovery is genetically different, whereas stability is genetically more equal.

Between parities are the traits genetically almost equal.

The resilience traits are positively correlated with other health traits, especially stability. Genetic correlations of stability with ketosis, fertility, metabolic disorders, longevity and udder health were highest ranging from 0.31 to 0.50.

Cows which are genetically resilient have less drops in milk production during a lactation and recover quicker when having a drop. Breeding for resilience leads to trouble-free animals, which can be seen as animal welfare, and an easy to manage herd.

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