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Fluctuations in milk yield are heritable and can be used as a resilience indicator to breed healthy cows

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ABSTRACT

Automatic milking systems record an enormous amount of data on milk yield and the cow itself. These type of big data are expected to contain indicators for health and resilience of cows. In this study, the aim was to define and estimate heritabilities for traits related with fluctuations in daily milk yield and to estimate genetic correlations with existing functional traits, such as udder health, fertility, claw health, ketosis, and longevity. We used daily milk yield records from automatic milking systems of 67,025 lactations in the first parity from 498 herds in the Netherlands. We defined 3 traits related to the number of drops in milk yield using Student *t*-tests based on either a rolling average (drop rolling average) or a regression (drop regression) and the natural logarithm of the within-cow variance of milk yield (LnVar). Average milk yield was added to investigate the relationships between milk yield and these new traits. ASReml was used to estimate heritabilities, breeding values (EBV), and genetic correlations among these new traits and average milk yield. Approximate genetic correlations were calculated using correlations between EBV of the new traits and existing EBV for health and functional traits correcting for nonunity reliabilities using the Calo method. Partial genetic correlations controlling for persistency and average milk yield and relative contributions to reliability were calculated to investigate whether the new traits add new information to predict fertility, health, and longevity. Heritabilities were 0.08 for drop rolling average, 0.06 for drop regression, and 0.10 for LnVar. Approximate genetic correlations between the new traits and the existing health traits differed quite a bit, with the strongest correlations (−0.29 to −0.52) between LnVar and udder health, ketosis, persistency, and longevity. This study shows that fluctuations in daily milk yield are heritable and that the variance of milk production is best among the 3 fluctuations traits tested to predict udder health, ketosis, and longevity. Using the residual variance of milk production instead of the raw variance is expected to further improve the trait to breed healthy, resilient, and long-lasting dairy cows.

Key words: fluctuation, resilience, health, variance, big data

INTRODUCTION

The world of dairy farming is changing; the number of farms is decreasing, whereas the number of dairy cows per farm is increasing. Therefore, an easy-to-manage herd becomes more important. For a farmer, it is easier to manage the herd when the animals are healthier. A healthy herd has fewer cases of diseases, which are costly and time-consuming for a farmer; furthermore, fewer cases of diseases would increase feed efficiency, which would help to feed the growing world population.

In dairy cattle, many diseases, such as milk fever, mastitis, ketosis, and lameness, often cause a decrease in milk yield (Rajala-Schultz et al., 1999; Windig et al., 2005; Onyiro et al., 2008). The pattern of the drop in milk yield differs. Milk fever can affect milk yield of cows for up to 6 wk, with a loss in milk production of 1.1 to 2.9 kg/d (Rajala-Schultz et al., 1999). For ketosis, for cows in parity 4 and higher, an average loss of 353.4 kg of milk per cow per 305-d lactation yield was estimated by Rajala-Schultz et al. (1999). For elevated SCC due to clinical or subclinical mastitis, the loss in milk yield was between 2 to 6 kg of milk per day (Windig et al., 2005). Drops in yield were more frequent in cows compared with heifers. In the first lactation, 56.9% of cows had a drop in daily milk yield of 2 kg, 30% had a drop of 4 kg, and 9% had a drop of 6 kg associated with high SCC. In higher-parity cows, these percentages were 68.5, 40.8, and 15.1%, respectively (Windig et al., 2005). The recovery also differs between the diseases, in time as well as in yield level that is reached after recovery (Rajala-Schultz et al., 1999; Windig et al., 2005; Onyiro et al., 2008).

In an earlier study, weak genetic associations were found between the variance in test-day milk yields and

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udder health and longevity (H. A. Mulder, unpublished data). The weak associations were likely due to the fact that test-day intervals are 4 to 6 wk. As a consequence, the effect of health issues on test-day milk yield could be small, especially when the health issue is short, subclinical, and in the middle of a test-day interval. Presently, many farmers record milk yields of every milking, using automatic milking systems (**AMS**) or electronic milk measurement systems. Fluctuations in daily milk yield of individual cows can be determined and the association between fluctuations in milk yield and animal diseases can be estimated more precisely compared with test-day records. Because animal diseases often cause drops in milk yield, fluctuations in daily milk yield are expected to be useful indicator traits for genetic evaluation of health and longevity in dairy cattle. So far, no research has been done on how to use fluctuations in daily milk yield as indicator traits for genetic evaluation of cow health. Therefore, the aim of our study was to estimate the heritability of various simple traits related to fluctuations in milk yield, to estimate genetic correlations among these fluctuation traits, and to estimate genetic correlations between these fluctuations traits with health and functional traits for which routine breeding values are estimated. Furthermore, we calculated partial genetic correlations and relative contributions to reliability to investigate which of the new traits is best at predicting fertility, health, and longevity. This study is the first exploring how daily milk yield records of AMS can be used to derive traits to improve fertility, health, and longevity of cows, and we discuss which steps are needed to implement such a trait for routine genetic evaluation.

MATERIALS AND METHODS

Data

The original data set for this study was obtained from CRV (Arnhem, the Netherlands) and contained 331,520 lactations collected from 1997 to 2016. The data consisted of records from AMS. Records of in total 182,064,264 milkings were provided with cow identification, milk yield in kilograms, the date, and the start and end time of each milking. Records for parity 1 were extracted. Cows that were at least 75% Holstein were used in the analysis. Cows were required to have records for at least 21 consecutive days and all records were used until d 335 after calving. To adjust for herd, year of calving, and season of calving, herd-year-season (**HYS**) classes were made with 20 possible years of calving (1997–2016) and 2 possible seasons of calving (January–June and July–December). The use of 3 or 4 seasons in the HYS decreased the data set by 15 and 20%, respectively, when the requirement of ≥5 lactations per HYS was used. With 2 seasons per year, the loss of data was only 2%. After the data edits, 498 herds with 67,025 lactations were used for analysis. Besides the milk yield data, the complete pedigree of the cows was available as well as the birthdates and the calving dates per parity for every cow.

Daily milk yield records were calculated based on the milk yields and the start times of each AMS milking (on average 2.8 times a day). Milking intervals in minutes between 2 consecutive milkings were calculated from the start time of the milking to the start time of the next milking. Milk yield of each single milking was converted to a 24-h day yield, based on kilograms of milk produced per minute using the time interval between 2 consecutive milkings. Subsequently, a day milk yield was calculated as the weighted average milk yield using the milk yields of each milking on that day and the length of the time intervals between consecutive milkings as weight factors. For the intervals longer than 1 d (>1,440 min), the milking was considered as missing value and not considered when calculating the weighted average day yield. When the day yield was higher than the average day yield of the whole data set plus 4 times the standard deviation of the whole data set, the day yield was considered as an outlier and therefore also set to a missing value.

Defining Fluctuations in Milk Yield

Fluctuations in milk yield were defined in 3 ways: the number of drops in milk yield during lactation either based on (1) a rolling average or (2) a regression and (3) the natural logarithm of the variance of milk yield of an individual cow per lactation.

For the rolling average method, the day yield was tested against the average of the preceding 7 d before the day of interest (d 8). Consequently, the first test was on d 8 in lactation, and the first 7 d were used to set the average for testing the next day yield. The Student′s t-test for the rolling average was $t = \left(y - \bar{\mu}\right) / \left(\mathrm{SD} / \sqrt{n}\right)$, where y is the d 8 yield, $\bar{\mu}$ is the rolling average over 7 d, SD is the standard deviation of the 7-d yields, and n is the number of day yields in the rolling average ($n = 7$). A significance threshold (α) of 1% was used for testing for a significant decreased day yield. The threshold 1% was arbitrarily chosen. The rolling average based on 7 d had 6 degrees of freedom (n − 1). A drop in day yield was significant when $t \leq -3.143$ (Ott and Longnecker, 2010). In preliminary research, we investigated also thresholds of 5 and 0.1%. Using a 0.1% threshold resulted in too few drops, and therefore heritabilities were very low, whereas results in