GENETIC EVALUATION OF LONGEVITY USING PRODUCTIVE LIFE AND SURVIVAL SCORES IN AUSTRALIAN HOLSTEIN CATTLE: PREDICTION OF EARLY SURVIVAL

M. Haile-Mariam[1,2], M. Khansefid[1,2], M. Axford[1,2,3], M.E. Goddard[1,4], and Jennie E. Pryce[1,2]

[1]Agriculture Victoria Research, AgriBio, Centre for AgriBioscience, Bundoora, Victoria, 3083, Australia
[2]School of Applied Systems Biology, La Trobe University, Bundoora, Victoria, 3083 Australia
[3]DataGene Ltd, 5 Ring Road, Bundoora, Vic. 3083, Australia.
[4]Faculty of Veterinary & Agricultural Science, University of Melbourne, Parkville, Vic. 3010, Australia.

SUMMARY

The accuracy of genetic and genomic evaluation for longevity is low due to the delay in the availability of culling data and low heritability (h^2). The h^2 and accuracy of genetic prediction for longevity is also influenced by trait definition and differences in methodologies used for estimating breeding values (EBV). This study was designed to compare the reliability, stability, and predictive ability of the current genetic evaluation of Australian dairy cattle for longevity which uses a survival score of 1 or 0 to an alternative measure that considers total months of in milk until 120 months of age (10 years). For this study, data from cows that completed their herd life (i.e., cows born before 2009, reference data) was used to assess differences in the ability of the two approaches for predicting early survival (i.e., survival to the maximum of the fourth lactation) for bulls of whose daughters were born in 2009 to 2014 (validation data). The h^2 of longevity, when the survival rate was analysed, was lower (0.04) than months in milk (0.08). However, the reliability of bull EBVs was about 10% higher for survival rate compared to months in milk. Moreover, EBV of bulls were more stable (i.e., higher correlation between EBVs) when longevity is defined as survival rate than as months in milk. Defining longevity as a survival rate provides better prediction accuracy for unobserved records than when defined as months in milk for bulls with at least 25 or more daughters in both reference and validation data. Overall reliability and stability of EBVs and prediction of unobserved phenotype is better when survival rate is used for genetic analyses than months in milk.

INTRODUCTION

Improving the longevity of cows increases profitability, animal welfare and reduces the environmental footprints of dairy production. The accuracy of genetic and genomic evaluation of longevity is low due to the delay in the availability of culling data and low heritability (h^2). The accuracy of genetic prediction for longevity is also influenced by the definition of the trait and differences in methodologies used for estimating breeding values (EBV) (Forabosco *et al*. 2009). Literature estimates show that longevity of cows when defined as productive life is more heritable (VanRaden and Klaaskate 1993; Settar and Weller 1999) than as survival rate (Madgwick and Goddard 1989) over the lifetime of the cow. However, quantifying differences between the two definitions of longevity in terms of predictive ability is important for increasing genetic progress and acceptance of the genetic evaluation results by end-users. This study was designed to compare the current genetic evaluation for longevity of dairy cattle in Australia which uses survival score 1 or 0 (Madgwick and Goddard 1989) to alternative measures such as productive life by estimating h^2, reliability, stability, and predictive ability of EBVs.

MATERIALS AND METHODS

Data of about 1.75 million Holstein-Friesian cows that were born between 1990 and 2014 from 9,742 dairy herds with valid cow termination dates were extracted from DataGene database for this study. From these data of 1.41 million cows that were born between 1990 and 2008 and that had opportunity to complete their herd life were used as a reference set. These data were used to estimate h^2 and breeding values (BV) for survival rate and total months of productive life (PL). Based on the termination dates we defined longevity in two ways at two time points in the life of the cows. The survival of cows from the first to subsequent lactations until 120 months of age (Surv120) or until the end of 7th parity (Surv7P) were coded as 1 for survived and 0 for culled. The same data was also used to defined productive life (PL) by adding the months in milk of cows in each lactation until 120 months of age (PL120) or until the 7th parity (PL7P). In all cases even if some cows were milked after 120 months of age or after 7th parity their survival rate or PL data was cut at the end of 120 months of age or 7th parity. The fixed effects that were included in the model were determined based on preliminary analyses. For survival rate (Surv120 and Surv7P), the fixed effects fitted were month and year of termination of lactations or of cows, the interaction between parity and age at calving, inbreeding of the cow (F) and month of calving and herd-year-season of calving. For PL, the fixed effects were age at 1st calving, F, the last month of calving and herd-year-season of birth. In all cases, the model included regressions on age at calving (linear and quadratic) and F (linear). When estimating h^2 and calculating reliability a sire model with numerator relationship matrix (NRM) based on sires and their ancestors was used. An animal model that considered all relationships up to 19 generations was used to calculate EBVs. ASReml was used for all data analyses (Gilmour *et al.* 2021).

Table 1. Description of the data with mean and standard deviation (SD) of the traits defined

Definition of longevity	No. records	Mean (SD) no. parities	Mean (SD) trait
Months in milk until parity 7, months	1,411,026^A	3.69 (2.02)	39.38 (22.68)
Months in milk until 120 months of age, months	1,411,026^A	3.65 (2.00)	38.80(21.84)
Survival until parity 7, %	5,204,131^B	3.69 (2.02)	81.94 (38.47)
Survival until 120 months of age, %	5,153,548^B	3.65 (2.00)	82.33 (38.14)

^{A} Number of cows; ^{B} Includes number of repeated records for cows with more than parity.

To compare genetic evaluation based on the two definitions of longevity, reliability of EBVs were calculated from the prediction error variance. For comparing stability, data of cows that were born before 2009 was split randomly into two. Then stability was calculated by correlating EBVs for sires estimated from two group of herds (even or odd herds) based on the two definitions of longevity. To assess the predictive ability of the two definitions of longevity, data of cows born after 2008 (validation data) were used to calculate corrected phenotype and was correlated with EBV estimated based on the data of cows born before 2009 (reference set). Bulls that had only parent average (PA), at least 25 or at least 50 daughters in the reference data and at least 25 or 50 daughters in the validation data were used to compare predictive ability.

RESULTS AND DISCUSSION

Table 1 show that the mean months in milk is the same (39 months) when productive life is cut at 120 months of age or at the 7th parity. Similarly in the case of survival rates, the mean survival rate (82%) is the same (Table 1), although including lactation until the end of the 7th parity increased the total number of records by about 1%. When calculating months in milk as a measure of longevity cows are sometime evaluated based on shorter age limit such as 84 months of age (VanRaden and Klaaskate 1993; Settar and Weller 1999). In Australia most cows stay longer in the herd than in several other countries (Schuster *et al.* 2020) so editing productive life at 120 months of age or 7th parity could be more appropriate. The h^2 of longevity when survival rate was used as the trait was lower (0.035-0.036) than when defined as months in milk (0.073-0.076). The higher h^2 for months in milk compared to survival rate observed in this study agrees with estimates in literature (Forabosco *et al.* 2009). Extending the lifetime of cows by 12 months, for both survival scores or months in milk until 132 months of age increased the h^2 to 0.04 or 0.08, respectively. However, the phenotypic correlation and correlation between EBV for bulls when survival rate or months in milk was set at 120 and 132 months was effectively 1 suggesting little benefit for delaying the completion of the data beyond 10 years.

Table 2. Mean EBV, standard deviation (SD), reliability (Rel) for bulls with at least 25 and 50 daughters for survival rate or months in milk up to the 7th parity and 120 months of age

Definition of longevity	**25 daughters** (7,035 sires)		**50 daughters** (3,224 sires)	
	Mean (SD)	Rel	Mean (SD)	Rel
Months in milk until parity 7	-0.49 (3.40)	0.57	-0.34 (3.59)	0.68
Months in milk until 120 months	-0.67 (3.20)	0.56	-0.53 (3.39)	0.67
Survival until parity 7	-1.29 (4.78)	0.68	-1.40 (4.98)	0.78
Survival until 120 months	-1.38 (4.72)	0.67	-1.47 (4.94)	0.77

Table 2 shows mean EBV with SD and reliability when longevity is defined in different ways. Reliability of EBVs for bulls were consistently higher (~ 10%) when longevity is defined as survival score than months in milk (Table 2). However, the difference in reliability varied from 0.07 for bulls with less than 3 records per daughter to 0.16 for bulls with more than 4 records per daughter. Completing survival or months in milk at end of 7th parity is only slightly more reliable than at 120 months of age. This is possibly due to the slightly higher h^2 and increased number of records when end of the 7th parity was used for editing data. The higher reliability of EBVs based on survival rate in the current study agrees with VanRaden (2003) who demonstrated that reliability of EBVs were higher when repeated survival rates were analysed instead of a single measure that represents the whole lifetime information of cows. The correlation between EBVs when PL is defined as months in milk until 120 months of age and until the end of parity 7 was effectively 1. Similarly, EBVs from survival rate had a correlation of 1.0 when the data ended at the 7th parity and at 120 months of age. As a result, further analyses that assessed stability and predictive ability were based on survival rates or months in milk up to 120 months of age. The correlation between EBVs from survival rate and months in milk for bulls with at least 5 daughters was only 0.72 and increased to 0.76 and 0.80 in bulls with at least 25 and 50 daughters, respectively, suggesting that the two definitions of longevity will rank bulls differently. However, the main reason for the below 1.0 correlation between the EBVs could be due to differences in modelling of fixed effects (VanRaden 2003) and the overall lower reliability of the EBVs of bulls due to the low h^2 of trait. In the current data with an increase in the number of daughters per sire the correlation between EBVs for survival rate and months in milk increased. For bulls with at least 200 or more daughters the correlation between the EBVs was 0.87.

By defining longevity as survival rate more stable EBVs (a correlation of 0.63 between EBVs from odd herds and even herds for bulls with at least 50 daughters in whole data) were obtained than months in milk (a correlation of 0.58). On the other hand, for bulls with at least 25 daughters defining longevity as months in milk up to 120 months of age produced more stable EBVs (a correlation of 0.55) compared to defining longevity as survival rate (a correlation of 0.49). For bulls with 10 or less daughters defining longevity as months in milk provides a slightly more stable EBV (a correlation of 0.05) than defining longevity as survival rate (a correlation of 0.02). However, it is worth mentioning that stability of EBVs is a useful measure of quality of EBVs only if the EBVs have a reasonably high level of accuracy. For bulls with 100 or more daughters the correlations between EBVs from odd and even herds (0.76) were higher when survival rate was used for genetic evaluation than months in milk (0.68) suggesting that the benefit of analysing survival rates on accuracy increases with increase in the number of progenies of the bulls.

Prediction of early survival of cows (i.e., survival to a maximum of the fourth lactation) whose data were excluded was consistently higher when survival rate was a measure of longevity than months in milk. For bulls with at least 25 and 50 daughters in the data of cows that were born before 2009 (i.e., reference) and that at least had 25 daughters in the data of cows that were born after 2008 (validation) the correlation between bull EBVs and corrected bull phenotypes was 0.47 (25 daughters) and 0.48 (50 daughters) when longevity was defined as survival scored compared to 0.39 (daughters) and 0.44 (daughters), respectively, when months in milk was analysed. For bulls with at least 50 daughters in the reference and validation data the correlation between EBV and corrected phenotype was 0.57 for survival score and lower at 0.52 for months in milk. For bulls with PA only in the reference set and at least 50 daughters in the validation set the correlation between PA and corrected phenotype was lower at 0.24 for survival rate and even lower at 0.17 for months in milk.

Higher reliability, stability, and predictive ability for EBVs for bulls are useful criteria when choosing trait definitions for genetic evaluation. It is worth noting that the increased benefit in terms of reliability when survival rates are used could be peculiar to Australian conditions where the number of repeated records is higher for cows that stay in the herd longer than conditions where most cows are culled after a few lactations. The most appropriate definition could also depend on extent of recording of termination data. In Australia, about 50% of the herds that participate in herd recording do not record termination data and survival status for cows in these herds is scored based on re-calving pattern in subsequent years which delays the availability of data (Madgwick and Goddard 1989) and also milk testing is less frequent making it difficult to determine the survival status of cows at any particular time. Accurate and complete recording of termination data will improve timelines and reliability of EBVs.

CONCLUSIONS

This current study showed that EBV of bulls are more reliable and stable when longevity is defined as survival rate rather than months in milk, although the h^2 was lower. Prediction ability for unobserved data of cows was also higher when survival rate is used compared to months in milk. Overall accuracy of genetic evaluation for longevity is higher when it is defined as survival score than as months in milk which means there is no justification to change the trait used for genetic evaluation of longevity in the current production environment.

ACKNOWLEDGEMENTS

This study was undertaken as part of the DairyBio research program, which is jointly funded by Agriculture Victoria, Dairy Australia sand the Gardiner Foundation (Melbourne, Australia). Data used in this study was collected by Australian dairy farmers and maintained by DataGene.

REFERENCES

Forabosco F., Jakobsen J. H. and Fikse W. F. (2009*) J. Dairy Sci.* **92:** 2338.

Gilmour A. R., Gogel B. J., Cullis B. R. and Thompson R. (2015) ASReml User Guide Release 4.0. VSN International Ltd., Hemel Hempstead, UK.

Madgwick P. A. and Goddard M. E. (1989). *J. Dairy Sci.* **72:** 2624.

Settar P. and Weller J. I. (1999). *J. Dairy Sci.* **82:** 2170.

Schuster J. C., Barkema H. W., De Vries A., Kelton D. F. and Orsel K. (2020*) J. Dairy Sci.* **103:** 11008.

VanRaden P. M. and Klaaskate E. J. H. (1993). *J. Dairy Sci.* **76:** 2758.

VanRaden P. M. (2003) Proc. Interbull Tech. Workshop, Beltsville, MD, Mar 2-3, *Interbull Bull.* 3**0**: 43.