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Article

Prediction model for productive life extension in censored records of Holstein cattle from Mexico

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Abstract:

The objective of this study was to predict months in production at 84 mo of age (MIP84) to include information from still-living animals in the genetic evaluation of longevity based on productive and reproductive information to establish complete longevity as MIP84. The records were obtained from animals born between 1986 and 2020 from the Holstein Association of Mexico. To predict MIP84, a linear regression model was fitted for 1st, 2nd, 3rd, 4th, and 5th calving before 84 mo of age. The model included information from cows with complete longevity, such as milk production in kilograms adjusted to 305 d ME (SP) at current calving, cumulative months in production before current calving (MACL), months in production at current calving (MLCC), pregnancy index at current calving (PRI), lactation status index at current calving (LAS), and age at first calving in months (AFC) in its linear and quadratic effects (AFC^2). The model explained 44 to 98 % of the variation observed in MIP84. Most regression coefficients for expanding longevity were significant and positive (P<0.01). The mean coefficient for PRI was negative in all calving's (-0.7159 ± 0.0171 and -2.0632 ± 0.0732). The proposed model allowed the inclusion of cows that have not yet finished their productive life, being of interest in genetic longevity assessments.

Keywords: Prediction model, Longevity, Holstein cows.

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Introduction

Longevity in dairy cattle is an important economic characteristic that presents genetic variability, generally low but sufficient for genetic progress in subsequent generations[1,2]. Countries that evaluate longevity in dairy cattle have measured it as herd life[3], productive life[3,4], functional longevity[5,6], true longevity[5,6], productive lifespan[7], longevity at 84 mo of age[8], longevity before culling or censorship[9], permanence[10], life expectancy[11,12], and milking life[13]. The low heritability estimates (0.02 to 0.11)[14] are the result of relatively high residual variability, which can be explained by the complexity of the trait and the considerable influence of environmental factors such as management. The productive life of dairy cows is difficult to improve genetically because, among other factors, complete data are available too late for the animals of interest, so an early selection of longevity, which would be appropriate, is impossible. Different authors have mentioned that improving longevity by identifying superior animals early is possible using correlated traits, as is the case of Maugan *et al*[15], who included, in their model, characteristics correlated with each other and with functional longevity, such as udder composition, fertility, somatic cell index, and incidence of mastitis, in order to include young animals in the early genetic evaluation of longevity in Holstein cattle; on the other hand, 13 type characteristics have been studied in Italian Montbeliarde cows, which were correlated with survival, allowing their early prediction[16]; other researchers used correlations of 15 type characteristics with herd life at 48 mo of age in Guernsey cattle[17]. Early selection can also be achieved with a nonlinear evaluation of censored data[18] or using predicted longevity for live cows in addition to complete longevity data[8,12]. The latter methodology is used in the United States of

America[8] to evaluate the longevity of dairy cattle measured as months in production at 84 mo of age (MIP84) because it allows the use of incomplete records from cows that are still alive at the time of evaluation, commonly called censored records. The process is based on the phenotypic prediction of MIP84 of animals not yet discarded based on population regressors to extend the productive lifespan and their subsequent adjustment to homologate variances, a process similar to that applied to the extension of incomplete lactations for the milk production trait[19]. In addition, since MIP84 is a continuous variable, it better represents the lifespan of a cow and brings the distribution of the variable closer to the normal distribution, allowing to have both complete data until the disposal of very old cows and censored data from younger cows[8]. In Mexico, the evaluation of longevity in Holstein cattle is done only for males using a survival model[20]; this is a limitation because early life indicators are needed to help farmers in the selection of animals that are more likely to reach their full potential; therefore, the use of MIP84 and a linear model will not only allow the evaluation of females to be carried out directly but will also allow genomic information to be included shortly. The first step to implement the evaluation of MIP84 in the Holstein population of Mexico is the prediction of the variable in animals that are still active or those whose true longevity is unknown for any reason; therefore, the objective of this study was to predict the months in production at 84 mo of age based on complementary productive and reproductive information in records of Holstein cows from Mexico, using the simple linear regression model developed by VanRaden and Klaaskate[8] and evaluating the fit of this model.

Material and methods

Information from the production control system of the Holstein Association of Mexico was used. The information included corresponded to the observed productive life of a total of 70,314 cows with 1 to 5 calving's because there were no cows that started their sixth lactation before 84 mo. The dependent variable was established as the months in production at 84 mo of age, establishing a maximum of 10 mo in production for each lactation so as not to indirectly favor cows with extended lactations[8]. In order to predict MIP84, the independent variables included in Van Raden and Klaasklate's[8] statistical model and those available at the end of each calving from 1 to 5 were used, which consisted of the accumulated months in production (MACL), months in production at the last calving (MLCC), the lactation status at the time of culling or termination of lactation (LAS), the pregnancy index at the time of culling or termination of lactation (PRI), the interaction of the herd-year and season of first calving and the age at first calving, and milk production measured in kilograms adjusted to 305 d mature equivalent (SP). Although this model[8] included the variable of dry days, these were not included in the model because they showed significant unexplained variations (analysis not presented in this study). The PRI was equal to 1 if the cow was pregnant; the cow was considered pregnant if it was more than 70 d after being artificially inseminated, it had a diagnosis of pregnancy, or it had a subsequent calving to the one analyzed, or zero in any other case. The lactation status index (LAS) was coded as zero when the cow was dry or in milking for more than 305 d and as one if the cow was in milking within 305 d. Age at first calving in months was also considered in its linear and quadratic effects.

Five scenarios were considered for the calculations, which represented the amount of information that the cow had for its prediction and depended on the number of complete lactations it had. That is, if it had finished its first or second lactation and so on until its fifth lactation. The number of cows that presented a complete calving was 26,704, two complete calvings 18,351, three complete calvings 10,496, four complete calvings 5,115, and up to five complete calvings 3,065. This differentiates the MIP84 calculated in this study from that obtained in the population of the United States of America, where the information they considered was obtained from different age groups(8). In other words, separate models were fitted for animals removed during their second, third, fourth, or fifth lactation, using the information generated up to the previous calving. Current calving was considered to be lactation during which the cow was removed.

The statistical model used for the prediction of MIP84 was as follows:

$$MEP84_{ijklmnopq} = \mu + hyfc_i + \beta_1 macl_j + \beta_2 mlcc_k + \beta_3 pri_1 + \beta_4 las_m + \beta_5 sp_n + \beta_6 afc_o + \beta_7 afc^2_p + \varepsilon_{ijklmnopq}$$

Where,
hyfc is the herd-year of first calving,
macl are the months in production accumulated until the previous calving,
mlcc are the months in production at the current calving,
pri is the pregnancy index at the current calving,
las is the lactation status at the current calving,
sp is the standardized milk production at 305 days ME at the current calving,
afc is the age at first calving,
afc² is the quadratic effect of age at first calving.
$\boldsymbol{\varepsilon_{ijklmnopq}}$ is the random error.
β_1, β_2, β_3, β_4, β_5, β_6, and β_7, are the coefficients of linear regressions for the variables described above. The GLM procedure of the SAS statistical software(21) was used to perform the analyses.

Results and discussion

Table 1 shows the regression coefficients, their probability value, and the coefficients of determination obtained from the model to predict MIP84 based on information from the first, second, third, fourth, and fifth calving. The model explained 98, 96, 92, 79, and 44 % of the variation from the effects included for MIP84 for the first to fifth calving, respectively.

Table 1: Coefficients of determination, regression coefficients, and *P*-value of the variables used in the prediction model for MIP84 in the first five calvings

Variable	MIP84				
	First calving	**Second calving**	**Third calving**	**Fourth calving**	**Fifth calving**
	Regression coefficient				
MACL, m	0.8951***	0.8188***	0.6669***	0.4123***	0.1414***
MLCC, m	0.0034^{NS}	0.0265***	0.0714***	0.1329***	0.1348***
LAS (0,1)	-0.0579**	0.0166^{NS}	0.1330^{NS}	0.1801^{NS}	0.1781^{NS}
PRI (0,1)	-0.7159***	-1.1221***	-1.7292***	-2.0632***	-1.4743***
SP, kg	0.0001***	0.0001***	0.0001***	0.0002***	0.0002**
R^2, %	98	96	92	79	44

MACL= months in production accumulated until the current calving, MLCC= months in production at the current calving, LAS= lactation status index (0= milking, 1= dry), PRI= pregnancy index (0= empty, 1= pregnant), SP= milk production in kg adjusted to 305 d ME at the current calving, R^2= coefficient of determination.

***= less than 0.001, **= between 0.001 and 0.01, *= between 0.011 and 0.05, NS= above 0.05

To explain the effect of the independent variables used in the model to predict MIP84 through the five calvings, MIP84 are shown directly since they are months in production already completed, and this is reflected in an increase in the MIP84 forecast. One-month increases were reported for the same variable[8]. The MLCC were significant from the second calving to the fifth and indicated that when increasing one month in milk in the current calving, the MIP84 increased by 0.026 for the second calving, by 0.071 for the third calving, by 0.133 for the fourth calving, and by 0.135 for the fifth calving; it may be due to two factors: one is the relationship between days in production and total milk production, since the higher the milk production, the lower the probability of discarding; and the other is that a cow with more months in production in the last lactation is closer to reaching the end of it and the possibility of starting a new lactation increases, and with this, the expectation of a higher MIP84 increases, in addition to the fact that, in general, these cows have a lower probability of having locomotion or health problems, they become pregnant more easily and have higher milk productions, which is consistent with what Dallago *et al*[22] stated.

Figure 1: Effect of the months in production accumulated until the current calving (MACL) on MIP84

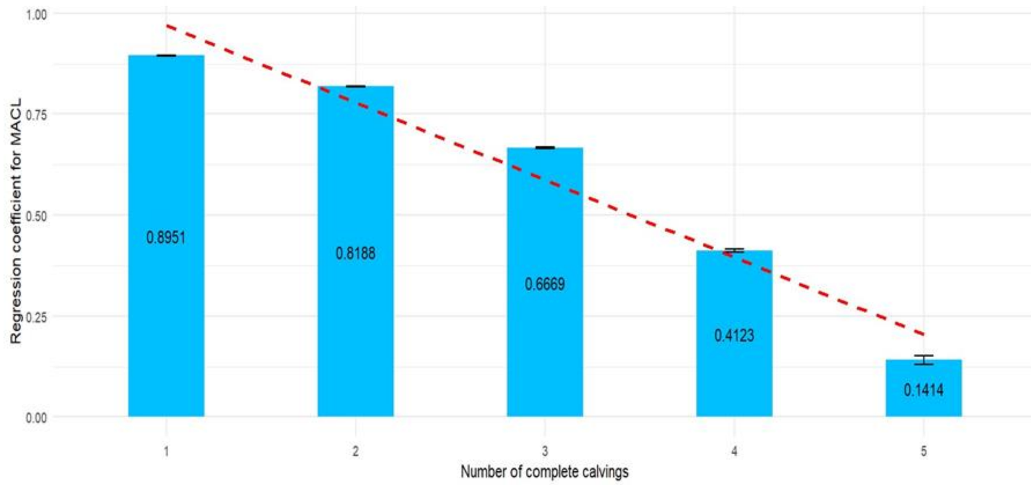
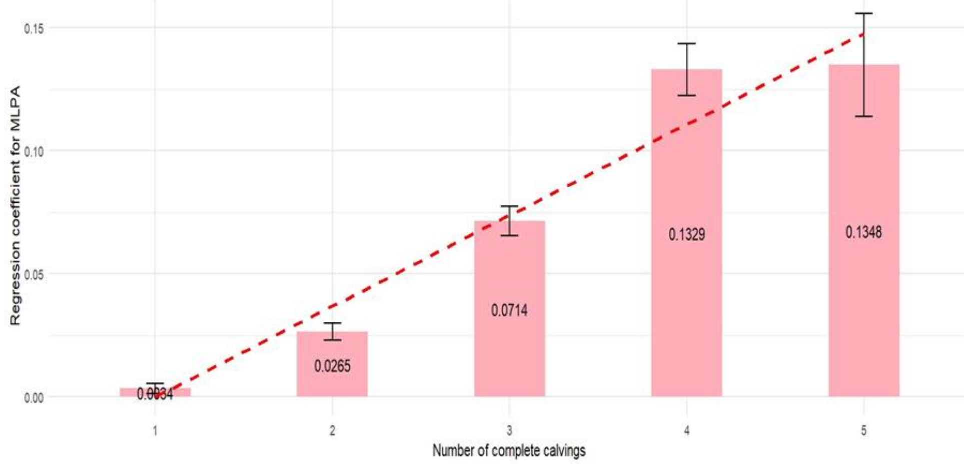


Figure 2: Effect of months in production at current calving (MLCC) on MIP84



The MLCC was not significant at first calving probably because of the distance in time between the MLCC of the first lactation and the date of discarding the cow. As the cow approaches the end of its productive life, MLCC tends to be important in predicting MIP84 because having more months of production in the previous lactation would predict that the cow stayed longer in the productive herd because it had a high production or greater fertility or better health; on the contrary, when there is a cow with a short previous lactation, in principle, it should have lower MIP84; this could be because the productive or reproductive conditions within the herd were not the best for the cow and caused it to have fewer months in production with a greater probability of being culled in the subsequent lactation. Although lactation status (LAS) regression coefficients were similar in magnitude to those of other characteristics, such as MLCC for calvings 2 to 5, they were only significant for the first calving. In the case of the first calving, when the cow is in milking, the prediction of MIP84 decreases by 0.06 months compared to when the cow is in the dry period (Figure 3). This could be because when the cow is primiparous and finishes its lactation without drying off, it is at a disadvantage against cows that end their cycle and become dry because they are less prepared to start a new productive cycle and thus decrease their expectation of MIP84. Contradictorily, when the cow finished its third lactation without drying off, the MIP84 prediction increased by 0.13 mo ($P<0.05$), probably because the cow is already close to reaching its actual MIP84 measurement, and the fact that it does not have information on the date of dry-off at this time is not as critical in the prediction of MIP84. On the other hand, when the cow was not pregnant (PRI) at the end of the previous lactation, the prediction of MIP84 was negative in the five calvings ($P<0.0001$), with a trend that indicates that it decreases as the number of calvings increases until it decreases by 2.06 mo at the fourth calving (Figure 4), which suggests that the fact that the cow has not ensured an upcoming calving at the time of prediction drastically decreases the predicted MIP84, which is consistent with what has been reported by several authors(1,23,24). Finally, the effect of SP on MIP84 was significant in the five calvings, indicating that when milk production increases by one kilogram, the predicted MIP84 increases by 0.0001 mo for the first three calvings and 0.0002 mo for the fourth and fifth calvings (Figure 5). This may reflect the fact that when cows have higher milk production, farmers tend to give them more opportunities to stay in the cowshed, increasing their MIP84(20). However, the large variation that exists in this variable makes the effect small compared to those of the other variables in the study. Age at first calving in its linear and quadratic effect was not significant in any calving.

Figure 3: Effect of lactation status (LAS) on MIP84

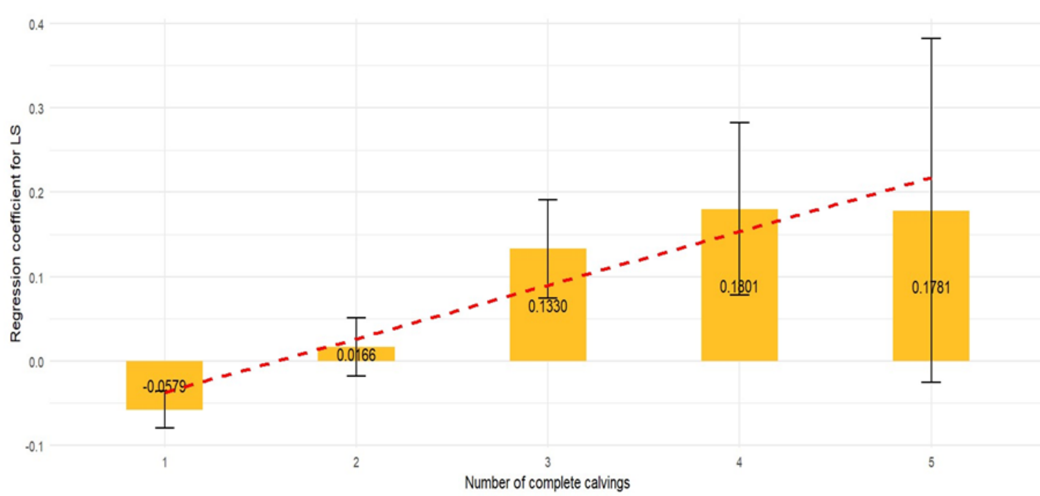


Figure 4: Effect of pregnancy index (PRI) on MIP84

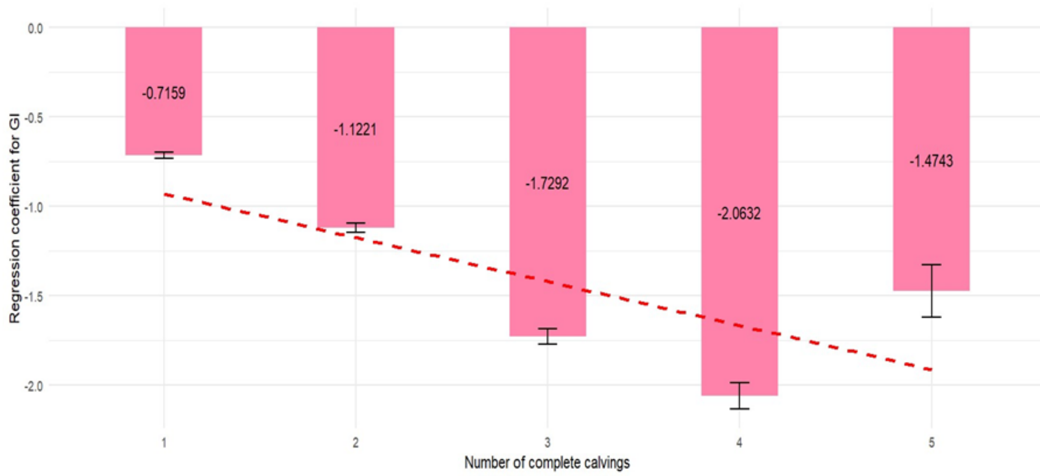
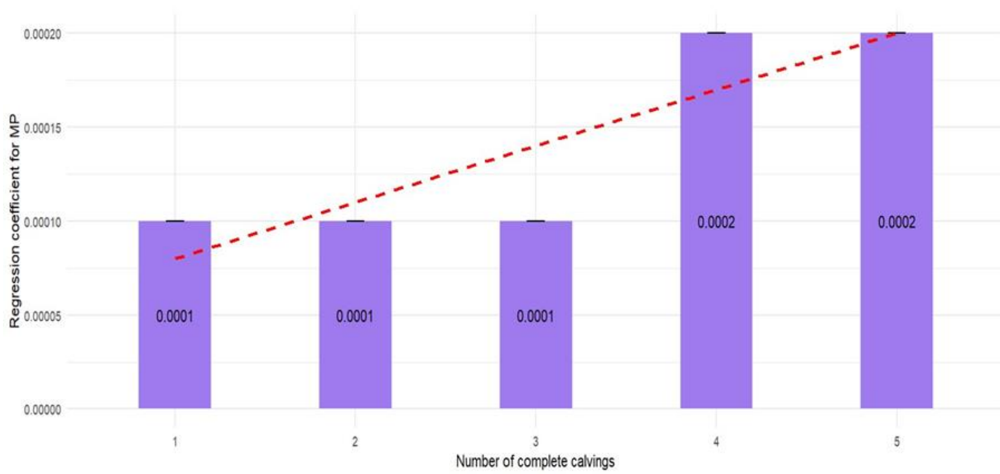


Figure 5: Effect of milk production at 305 days of ME (SP) on MIP84



Conclusions and implications

According to the results obtained in this study, it is possible to predict with high accuracy MIP84 in Holstein dairy cows, with at least one lactation completed, based on the milk production in kilograms adjusted to 305 days ME, the accumulated months in production, the months in production of the last lactation, whether the cow is in production or dry and whether it is pregnant or not, common variables in milk production controls. On the other hand, the predicted MIP84 was higher for cows with more months in production at their last recorded full lactation, cows that were in production at their last record (except second-lactation cows), or cows that were pregnant at the end of the last lactation. The prediction of

MIP84 will allow animals that have not finished their productive life to be included in the genetic evaluation of this population, information that will help producers in the genetic improvement of longevity in their herds.

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Literature cited:

1. Hu H, Mu T, Ma Y, Wang X, Ma Y. Analysis of longevity traits in Holstein cattle: A Review. Front Genet 2021;(12):1-15. doi:10.3389/fgene.2021.695543.

2. De Vries A. Economic trade-offs between genetic improvement and longevity in dairy cattle. J Dairy Sci 2017;100(5):4184-4192. doi:10.3168/jds.2016-11847.

3. Tsuruta S, Misztal I, Lawlor TJ. Changing definition of productive life in US Holsteins: Effect on genetic correlations. J Dairy Sci 2005;88(3):1156-1165. doi.org/10.3168/jds.S0022-0302(05)72782-X.

4. Costa A, Bovenhuis H, Penasa M. Changes in milk lactose content as indicators for longevity and udder health in Holstein cows. J Dairy Sci 2020;103(12):11574-11584. doi.org/10.3168/jds.2020-18615.

5. Vukasinovic N, Moll J, Künzi N. Analysis of productive life in Swiss Brown cattle. J Dairy Sci 1997;80(10):2572-2579. doi.org/10.3168/jds.S0022-0302(97)76213-1.

6. Sasaki O, Aihara M, Hagiya K, Nishiura A, Ishii K, Satoh M. Genetic evaluation of the longevity of the Holstein population in Japan using a Weibull proportional hazard model. Anim Sci J 2011;83(2):95–102. doi:10.1111/j.1740-0929.2011.00943.

7. Caraviello DZ, Weigel KA, Gianola D. Prediction of longevity breeding values for US Holstein sires using survival analysis methodology. J Dairy Sci 2004;87(10):3518–3525. doi:10.3168/jds.S0022-0302(04)73488.

8. VanRaden PM, Klaaskate EJH. Genetic evaluation of length of productive life including predicted longevity of live cows. J Dairy Sci 1993;(76):2758-2764.

9. Raguz N, Jovanovac S. Analysis of the relationships between type traits and longevity in Croatian Simmental cattle using survival analysis. Agric Conspec Sci 2011;76(3):249-253.

10. Brickell JS, Wathes DC. A descriptive study of the survival of Holstein-Friesian heifers through to third calving on English dairy farms. J Dairy Sci 2011;(94):1831-1838. http://dx.doi.org/10.3168/jds.2010-3710.

11. Van Pelt M, Meuwissen THE, De Jong G, Veerkamp RF. Genetic analysis of longevity in Dutch dairy cattle using random regression. J Dairy Sci 2015;98(6):4117-4130. https://doi.org/10.3168/jds.2014-9090.

12. Brotherstone S, Veerkamp RF, Hill WG. Predicting breeding values for herd life of Holstein-Friesian dairy cattle from lifespan and type. Anim Sci 1998;(67):405–411.

13. Zhang H, Liu AY, Wang H, Luo X, Yan X, Guo X, Li L, Liu, Su G. Genetic parameters and genome-wide association studies of eight longevity traits representing either full or partial lifespan in Chinese Holsteins. Front Genet 2021;(12):634986. https://doi.org/10.3389/fgene.2021.634986.

14. Forabosco F, Jakobsen JH, Fikse WF. International genetic evaluation for direct longevity in dairy bulls. J Dairy Sci 2009;(92):2338–2347.

15. Maugan LH, Rostellato R, Tribout T, Mattalia S, Ducrocq V. Combined single-step evaluation of functional longevity of dairy cows including correlated traits. Genet Sel Evol 2023;55(75):1-15. https://doi.org/10.1186/s12711-023-00839-6.

16. Kern EL, Cobuci JA, Costa CN, McManus CM, Campos GS, Almeida TP, *et al.* Genetic association between herd survival and linear type traits in Holstein cows under tropical conditions. Ital J Anim Sci 2014;(13):665–672.

17. Harris BL. Linear programming applied to dairy cattle selection [doctoral thesis]. Iowa, USA: University of Iowa State; 1992. https://lib.dr.iastate.edu/rtd/9997.

18. Mészáros G, Sölkner J, Ducrocq V. The Survival Kit: Software to analyze survival data including possibly correlated random effects. Computer methods and programs in biomedicine 2013;110(3):503-10. https://doi.org/10.1016/j.cmpb.2013.01.010.

19. VanRaden PM, Dematawewa CM, Pearson RE, Tooker ME. Productive life including all lactations and longer lactations with diminishing credits. J Dairy Sci 2006;89(8):3213-3220. doi:10.3168/jds.S0022-0302(06)72596-6.

20. Abadía JR, Ruíz FJ, Vega VE, Montaldo HH. Análisis genético para vida productiva en ganado Holstein de México. Rev Mex Cienc Pecu 2016;7(1):1-14. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S2007-11242016000100001&lng=es.

21. SAS. SAS/STAT User´s Guide (version 9.4 ed.). Cary NC, USA: SAS Inst. Inc. 2010.

22. Dallago GM, Wade KM, Cue RI, McClure JT, Lacroix R, Pellerin D, *et al*. Keeping dairy cows for longer: a critical literature review on dairy cow longevity in high milk-producing countries. Animals 2021;(11):808. https://doi.org/10.3390/ani11030808.

23. Pipino DF, Piccardi M, Lopez-Villalobos N, Hickson RE, Vázquez MI. Fertility and survival of Swedish Red and White × Holstein crossbred cows and purebred Holstein cows. J Dairy Sci 2023;106(4):2475-2486. doi:10.3168/jds.2022-22403.

24. Essl A. Longevity in dairy cattle breeding: A review. Livest Sci 1998;(57):79–89. doi .org/10 .1016/ S0301-6226(98)00160-2.