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Communication

Dairy Cow Longevity Is Affected by Dam Parity and Age

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Abstract: The objective of this study was to determine whether the parity and age of dams affect the longevity of their offspring in dairy cows in pasture-based systems. A total of 12,792 dairy cows born between 2000 and 2017 across five farms were evaluated using records from the Dairy Herd Improvement Database at Instituto Nacional para el Control y Mejoramiento Lechero (Uruguay). Dams were classified as primiparous or multiparous, and parity number and age were considered. The effect of parity status on herd life (HL), the length of productive life (LPL), and the productive life index (PLI) was evaluated using a generalized mixed model. Associations between parity number and dam age with HL, LPL, and PLI were evaluated using regression models. HL, LPL, and PLI were significantly higher for daughters of multiparous cows. Dams with more parities gave birth to longer-living daughters, with an average HL difference of 4.4 months between the first and seventh parity of the dams. The parity number and age of the dam showed a significant association with HL, LPL, and PLI. In conclusion, the parity and age of the dam influence the longevity of dairy cows in pasture-based systems, with older dams and higher parity yielding daughters with greater longevity.

Keywords: herd life; length of productive life; pasture-based production

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1. Introduction

Dairy cow longevity is an indicator of health, biological functioning, and animal welfare, as well as a performance indicator for the dairy business [1,2]. Several factors have been reported to affect the longevity of dairy cows, such as genetics, health, environment, season and decade of birth, and the farmer's culling decisions [3,4]. However, the effects of maternal factors, such as the parity and age of the dam, on cow longevity have not yet been explored. It is known that primiparous and multiparous cows differ in metabolic, physiological, and behavioral aspects. For example, during gestation, primiparous cows have lower placental, cotyledonary, and intercotyledonary weights [5,6] and shorter gestation lengths [7]. During perinatal events, primiparous cows produce less colostrum [8] with lower concentrations of immunoglobulins [9]. Additionally, primiparous cows spend less time licking the calf and more time moving or kicking when the calf is seeking the udder compared to multiparous cows [10]. Regarding their offspring, primiparous cows have higher neonatal mortality rates [11,12] and produce calves with lower birth weights [7]. Considering these differences between primiparous and multiparous dams, it is possible to speculate about their impact on the development and longevity of the offspring. Most information on the effect of the parity of dairy cows on their offspring is focused on short periods up to weaning [13]. However, there is a gap in knowledge regarding the long-term effects of the dam parity on the longevity of the offspring.

Based on the aforementioned information, we hypothesized that dam parity and age affect a cow's longevity, with the daughters of primiparous dams having the lowest longevity. Therefore, the aim of this study was to determine whether the parity and age of dams in dairy cows affect the longevity of their offspring in a temperate climate and pasture-based production system.

2. Materials and Methods

2.1. Data

Data records were extracted from the Dairy Herd Improvement Database at the Instituto Nacional para el Control y Mejoramiento Lechero Uruguay. This database contains information on health, reproduction, production, milk quality, and management of dairy farms. The information is voluntarily uploaded by associated farmers, farm technicians, and milk quality laboratory technicians.

Available information such as the date of birth, date of first calving, and culling (or death) date was used to calculate herd life (HL) and length of productive life (LPL), as reported by Bobadilla et al. [4]. HL was defined as the number of months between birth and culling or death, while LPL was defined as the number of months between first calving and culling or death, as proposed by Schuster et al. [14]. For each cow, the number of parities of the dam was used to classify the cow as primiparous or multiparous. We defined a new index, called the "productive life index (PLI)", which is calculated as LPL divided by HL expressed as a percentage. The variable season of birth with four levels was defined as follows: summer: December to February, autumn: March to May, winter: June to August, and spring: September to November.

2.2. Exclusion and Inclusion Criteria

To select the animals for this study, the following criteria were used:

2.2.1. Exclusion Criteria

- No male animals were considered;
- No cows culled before first calving were considered;
- Cows with HL greater than 240 months and cows with age at first calving (AFC) under 20 months and over 48 months were excluded.

2.2.2. Inclusion Criteria

- All the farms considered were pasture-based dairy farms;
- Farms with at least 1800 cows born with complete series of observations of births between the years 2000 and 2017 and belonging to the same geographical area (south-western Uruguay) were selected;
- A maximum of 7 lactations for the dams were considered;
- Age restriction intervals were defined for dam age with a minimum of 20 months for age at first calving and a maximum of 130 months of age for the 7th lactation;
- The end of the study period was 1 July 2021.

2.3. Statistical Analysis

2.3.1. Categorical Explanatory Variables

To evaluate the effects of dam parity on HL, LPL, and PLI, two generalized linear mixed models (GLMMs) were fitted using data of 12,792 cows (90% Holstein, 10% Jersey and crossbreeds) from five farms. The response variables were assumed to follow a normal distribution, and an identity link function was applied. A compound symmetry covariance structure was used, and the best-fitting model was determined by examining the residuals and the Restricted Maximum Likelihood (REML) criterion at convergence. The first model included the fixed effects of parity status of the dam (primiparous vs multiparous) and season of birth, and the random effects of herd, birth year, dam, and residual. The second model included the same factors as model one, but the dam parity was split into 7 parities:

$$yijklmn = \mu + Pi + Sj + \upsilon k + \xi l + \zeta m + \varepsilon ijklmn$$

where:

yijklmn = response variables HL, LPL, or PLI;
μ = population mean;
Pi = ith fixed effect of the parity status (primiparous, multiparous) or parity number;
Sj = jth fixed effect of the season of birth (four classes: spring, summer, autumn, winter);
υk = random effect of the kth herd (5 herds);
ξl = random effect of the lth dam (9317 dams);
ζm = random effect of the mth year;
εijklmn = random residual error.

2.3.2. Regression Analysis

To evaluate the magnitude of change associated with each increase in dam parity (considered as a numerical discrete variable with values between 1 and 7) on HL, LPL, and PLI, we performed an analysis of covariance using the following mixed linear model:

$$yijklmn = \mu + \beta 1pijklmn + Sj + \upsilon k + \xi l + \zeta m + \varepsilon ijklmn$$

where:

γjklmn = response variables HL, LPL, or PLI;
μ = population mean;
β1 = the linear regression coefficient of parity number of the dam on the response variable for observation pijklmn;
Sj = jth fixed effect of the season of birth (four classes: spring, summer, autumn, winter);
υk = random effect of the kth herd (5 herds);
ξl = random effect of the lth mother (9317 mothers);
ζm = random effect of the mth year;
εijklmn = random residual error.

The linear effect of age of dam (treated as a numerical continuous variable) on the response variables was evaluated with same model as described above, but replacing dam parity by dam age (years).

2.4. Software

Tidying and filtering of the data were performed using the statistical software R (version is 4.1.2). The following packages were used: “tidyverse” [15] for data editing, “lubridate” [16] for date manipulation, and “lmerTest” [17] for the GLMM. The Tukey test was used for multiple comparisons. For all statistical tests, the significance level considered was alpha = 0.05.

3. Results

For the 12,792 cows studied, the mean HL was 72.2 months (SD = 27.2), the mean LPL was 42.4 months (SD = 26.9), and the mean PLI was 52.9% (SD = 17.7%).

3.1. Categorical Explanatory Variables

3.1.1. Parity Status

The three longevity metrics were greater in the daughters of multiparous dams compared to those of primiparous dams (Table 1).

Table 1. Least squares means and standard errors of herd life (HL), length of productive life (LPL), and productive life index (PLI; percentage of LPL divided by HL) of dairy cows born from primiparous and multiparous dams.

Dam Parity	N	HL (Months)	LPL (Months)	PLI (%)
Primiparous	4638	72.99 ± 3.79^{a}	42.93 ± 3.75^{a}	52.68 ± 2.68^{a}
Multiparous	8154	73.95 ± 3.78^{b}	43.84 ± 3.74^{b}	53.37 ± 2.67^{b}

Means with different superscript letters within the column are significantly different ($p < 0.05$).

3.1.2. Parity Number

The longevity of the daughters increased with the number of lactations of their dams (Table 2).

Table 2. Least squares means and standard errors of herd life (HL), length of productive life (LPL), and productive life index (PLI; percentage of LPL divided by HL) of dairy cows according to the parity number of their dams.

Dam Parity	N	HL (Months)	LPL (Months)	PLI (%)
1st	4638	72.99 ± 3.79^{c}	42.93 ± 3.75^{c}	52.68 ± 2.68^{b}
2nd	3195	73.07 ± 3.80^{bc}	43.08 ± 3.76^{bc}	52.96 ± 2.68^{b}
3rd	2184	74.10 ± 3.81^{abc}	43.89 ± 3.77^{abc}	53.44 ± 2.68^{b}
4th	1409	74.08 ± 3.82^{abc}	43.86 ± 3.79^{abc}	53.22 ± 2.70^{b}
5th	785	74.87 ± 3.87^{ab}	44.80 ± 3.82^{ab}	53.78 ± 2.72^{ab}
6th	397	76.24 ± 3.96^{a}	46.06 ± 3.92^{a}	55.22 ± 2.78^{a}
7th	184	77.39 ± 4.17^{a}	47.28 ± 4.13^{a}	54.94 ± 2.92^{ab}

Means with different superscript letters within each response variable indicate significant differences ($p < 0.05$).

3.2. Regression Analysis

Dam parity and dam age had similar results for the three metrics considered.

The linear effect of dam parity was significant on the following metrics of the daughters: HL (β = 0.56, SE = 0.15, $R^2 = 0.32$, $p < 0.001$), LPL (β = 0.54, SE = 0.15, $R^2 = 0.29$, $p < 0.001$), and PLI (β = 0.34, SE = 0.10, $R^2 = 0.26$, $p < 0.001$).

Similarly, the linear effect of dam age was significant on the following metrics of the daughters: HL (β = 0.48, SE = 0.12, $R^2 = 0.32$, $p < 0.001$), LPL (β = 0.43, SE = 0.12, $R^2 = 0.29$, $p < 0.001$), and PLI (β = 0.23, SE = 0.08, $R^2 = 0.25$, $p = 0.004$).

4. Discussion

This study is the first to report that dam parity and age affect the longevity of dairy cow offspring in a pasture-based production system. Compared to daughters of primiparous dams, daughters of multiparous dams had greater longevity. Additionally, daughter longevity increased with the number of parities of the dams, as evidenced by the positive association between dam parity number and dam age with the longevity of the offspring.

Several biological and productive factors differentiate cows between parities, with the most noticeable differences reported between primiparous and multiparous cows. These differences impact the newborn and not only affect short-term survival but also likely have long-term effects on lifespan. There are differences in dam parity during two critical periods, pregnancy and the perinatal period.

During pregnancy, primiparous and multiparous cows have metabolic and physiological differences that affect the development of the offspring. In general, primiparous cows have not yet reached adult size and weight when they calve, so energy resources must be distributed between dam growth and fetal development (nutrient partitioning) [18]. These metabolic and developmental differences between primiparous and multiparous dams can impact fetal development. Another possible factor is the lack of physiological experience of the primiparous dam during pregnancy, as tissues like the uterus are being used for the first time [13]. Primiparous cows have lower placental, cotyledonary, and intercotyledonary weights and smaller cotyledonary surface areas [6], factors associated with placental function, which is a determinant of fetal growth and is key for the lifelong health of the offspring [19]. Due to placental conditions and nutritional partitioning, offspring of primiparous cows might be exposed to nutritional and energetic restrictions during gestation, resulting in reduced longevity, as observed in other animal models [20]. Moreover, gestation length has been reported to be shorter in primiparous than in multiparous cows [7]. In addition, shorter gestational length is associated with a reduced lifespan of the offspring [21]. These factors could help explain our findings that the offspring of primiparous dams have lower longevity than those of multiparous dams. Further studies are required to understand the underlying mechanisms of how the parity of the dam during pregnancy affects the longevity of the offspring.

During the perinatal period, an additional set of factors distinguishes primiparous from multiparous dairy cows. Primiparous cows have a higher incidence of dystocia or require more assistance at birth [22] and tend to give birth to calves with lower birth weights [23,24]. These two factors, ease of calving and birth weight, negatively affect the longevity of the offspring [25]. Behaviorally, primiparous cows take longer to stand up after giving birth [26] and spend less time licking their calves [10], a behavior that, among other functions, enhances general body hygiene and reduces the risk of infection. Additionally, primiparous dams spend more time moving or kicking the calf while it is seeking the udder [10], thus restricting access to the udder and affecting colostrum consumption by the newborn. Regarding colostrum, primiparous cows have a lower yield [8], lower concentrations of immunoglobulins [9,27], and a lower protein concentration [28] than multiparous mothers. Higher colostrum consumption is associated with lower culling rates [29]. Additionally, offspring born from primiparous mothers have lower levels of serum immunoglobulins, total protein, globulin, gamma-glutamyl transferase [9], hematocrit, and hemoglobin [28]. Higher concentrations of immunoglobulins in the 30 to 60 h after birth are associated with lower morbidity and intensity of disease in calves; moreover, heifers show better health status and reach body weights that allow insemination sooner [30]. These factors can not only affect the early survival of the calf but also have long-term effects on its development and health, ultimately influencing its longevity.

Considering the parity number of the dam beyond just primiparous or multiparous classification allows for deeper insights into differences within the multiparous group. Our findings showed similar results for HL, LPL, and PLI when the effect of dam parity and dam age were evaluated as explanatory variables in the GLMM. These results reflect the association between age and successive parities that a cow undergoes in the dairy system, where regular calving intervals are required [19]. Hence, the analyses are discussed together. Maternal age has been reported to affect offspring performance. For production, energy-corrected milk decreases with the age of the dam [31], and high-yield cows tend to be daughters of younger dams [23,32]. Nevertheless, offspring of older multiparous cows have a greater first-service conception rate, require fewer services for conception, and have a shorter calving-to-conception interval than offspring of primiparous or young multiparous dams [23]. Considering that dairy cow longevity is influenced by the farmer's culling decisions, where production, health, and reproduction are key criteria, these reproductive differences between younger and older cows could explain our results, where farmers might tend to prioritize efficient reproduction over production under these conditions.

The management system of the dairy cow is unique, as it allows for the study of the effect of dam parity (from gestation to peripartum) on the longevity of the calf while isolating possible effects related to parental care. This is because, in dairy cows, the calf is separated from the mother a few hours after birth. These elements differentiate the dairy cow from other ruminants and species [33–35], where offspring longevity is strongly influenced by maternal care, not only during lactation but also during post-weaning periods. This study demonstrates that dam parity and dam age influence the longevity of dairy cows, even when contact time between the mother and calf is minimal and limited to only a few hours postpartum.

It is important to acknowledge some limitations of our study. While the primary objective was to assess the effects of dam parity and age on the longevity of dairy cows, additional data on specific farm practices could further support the ideas previously discussed. In particular, information on farm management practices, such as those related to calf rearing. For example, knowing the precise timing between birth and calf–dam separation, information on colostrum administration practices, including whether colostrum was artificially supplied, and the subsequent management of calves on each farm, could offer valuable insights. These limitations raise new questions for future research. Additionally, while heritability estimates for longevity suggest that selection for this trait is feasible and many dairy cattle breeding programs include it in their selection indexes [36], reports on maternal genetic effects on the longevity of dairy cows were not found in the literature. Thus, exploring the genetic aspects linked to maternal influence on offspring longevity represents another interesting area for future investigation.

5. Conclusions

This study demonstrates that in dairy cows within a temperate climate and pasture-based production system, the parity and age of the dam affect the longevity of the daughter. Daughters of multiparous dams had the highest values for the longevity metrics (HL, LPL, and PLI). Both dam parity and age were positively associated with these metrics, resulting in older dams producing daughters with higher values for HL, LPL, and PLI.

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Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy restrictions.

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