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Keeping Dairy Cows for Longer: A Critical Literature Review on Dairy Cow Longevity in High Milk-Producing Countries †

Gabriel M. Dallago [1,*], Kevin M. Wade [1], Roger I. Cue [1], J. T. McClure [2], René Lacroix [3], Doris Pellerin [4] and Elsa Vasseur [1]

[1] Department of Animal Science, McGill University, Sainte-Anne-de-Bellevue, QC H9X 3V9, Canada; kevin.wade@mcgill.ca (K.M.W.); roger.cue@mcgill.ca (R.I.C.); elsa.vasseur@mcgill.ca (E.V.)
[2] Department of Health Management, Atlantic Veterinary College, University of Prince Edward Island, Charlottetown, PE C1A 4P3, Canada; jmcclure@upei.ca
[3] Lactanet, Sainte-Anne-de-Bellevue, QC H9X 3R4, Canada; rlacroix@lactanet.ca
[4] Département des Sciences Animales, Université Laval, Québec, QC G1V 0A6, Canada; doris.pellerin@fsaa.ulaval.ca
* Correspondence: gabriel.dallago@mail.mcgill.ca
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Abstract: The ability of dairy farmers to keep their cows for longer could positively enhance the economic performance of farms, reduce the environmental footprint of the milk industry, and provide overall help in justifying a sustainable use of animals for food production. However, there is little yet published on the current status of cow longevity and we hypothesized that a reason may be a lack of standardization and an over narrow focus of the longevity measure itself. The objectives of this critical literature review were: (1) to review the metrics used to measure dairy cow longevity in order to determine those most commonly employed; (2) to describe the status of longevity in high milk-producing countries. Current metrics are limited to either the length of time the animal remains in the herd or if it is alive at a given time. To overcome such a limitation, dairy cow longevity should be first defined as an animal having an early age at first calving and a long productive life spent in profitable milk production. Combining age at first calving, length of productive life, and margin overall costs would provide a more comprehensive evaluation of longevity by covering both early life conditions and the length of time the animal remains in the herd once it starts to contribute to the farm revenues, as well as overall animal health and quality of life. In addition, this review confirms that dairy cow longevity has decreased in most high milk-producing countries over time and its relationship with milk yield is not straight forward. Increasing cow longevity by reducing involuntary culling would cut health costs, increase cow lifetime profitability, improve animal welfare, and could contribute towards a more sustainable dairy industry while optimizing dairy farmers' efficiency in the overall use of resources available.

Keywords: animal use; animal welfare; cow longevity; productive lifespan; profitability; sustainability

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1. Introduction

Dairy cow longevity is determined by either the culling decision made by the producer or the death of the animal and is linked to the economic performance of farms, the environmental footprint of the milk industry, and the welfare status of the animals [1–4]. Short longevity indicates that animals are not expressing their maximum potential for productivity and profitability, since dairy cows become profitable at their third lactation due to high costs associated with the early life non-productive stage [3,4]. Comparatively, an increase in length of productive life is associated with a decrease in methane emission per kg of milk produced [2], which contributes to decreasing the footprint associated with milk production [1]. Lastly, cow longevity is a global indicator of animal welfare since higher cow longevity indicates that the animal's biological functions and health are not impairing the length of its life [5]. In addition, the health issues associated with the most common reasons for early cow removal bring into question welfare conditions and ethical concerns involved in dairy farming [6].

This critical literature review provides an integrated view of dairy cow longevity combined with analysis of its status by focusing on the phenotypical aspect of longevity rather than its genetic aspect. The objectives were to (1) review metrics commonly used to measure dairy cow longevity and (2) use the most common metric to describe the status of longevity in high milk-producing countries. We hypothesized that considerable limitations exist in current longevity metrics such as the lack of both a standard metric and standard reporting by dairy herd improvement (DHI) agencies or national databases but, despite these limitations, we would be able to demonstrate that dairy cow longevity has decreased over the years in most high milk-producing countries. The overall aim of this review is to propose a more comprehensive definition of cow longevity, which could help farmers enhancing the length of time cows remain in their herds while helping to justify a more sustainable use of animals to produce food products.

2. How Can We Measure Longevity?

The longevity of dairy cows is influenced by culling decisions made by the dairy farmer since culling ultimately defines the total length of time a cow remains in the herd. Therefore, common longevity metrics reflect culling strategies as well as the different stages of the life of a dairy cow.

Culling is the process of removing an animal from the herd due to death, salvage, sale, or slaughtering [7]. It can be further classified as voluntary when a fertile and healthy animal is culled due to low milk production or involuntary if low milk production is not the culling reason [7,8]. Involuntary culling accounts for most of the removal of dairy cows when reasons are known. For example, in Canada, the average involuntary culling was 73.6% (Standard deviation; SD = 0.65) between 2014 and 2019, while the averages of voluntary culling and culling with unknown reason were 7.18% (SD = 0.28) and 20.7% (SD = 2.3), respectively, in the same period [9]. Reproduction, mastitis, and feet and leg problems are the main reasons for involuntary culling [9,10] and their prevalence has remained stable over time in different countries, while there was a decrease in culling due to low milk production (voluntary culling), likely due to the genetic selection for high milk-yielding cows, which reduces the relative risk of being culled due to low milk production [11].

Longevity metrics can be classified either as stayability or lifetime metrics. Stayability metrics have a binary nature and indicate if a dairy cow is alive at a given moment in time [12] and can be updated as the animal grows. An example would be if cows reach the third or greater lactation [13]. Even though such metrics do not provide a complete picture of cow longevity, one of their advantages is that they can be measured at any time [12]. On the other hand, lifetime metrics take into account the completed life stages of the animals [12]. For example, the life of a dairy cow can be split into early life (non-productive) and productive stages from a production perspective. Based on this, longevity can be measured as the length of the productive life of a dairy cow [14,15]. Since lifetime metrics take into account an entire stage of life, they can only be calculated when such stage is completed, which is one of the main limitations of such metrics. In addition, most lifetime metrics do not account for the early life stage since they typically have first calving as the starting point. Lastly, there is no standard metric to measure dairy cow longevity and, even though each different metric reflects an aspect of dairy cow longevity, they are not comparable since they do not have the same meaning [16].

3. What Is the Current Status of Dairy Cow Longevity and Milk Yield?

The average length of productive life, which is one of the most common longevity metrics, can be estimated based on the culling rate [6,17]. Since information at country level regarding culling is not available for most countries, a proxy can be estimated based on slaughtering data at country level, even though this approach would not take into account animals that died on the farm and would assume the accuracy of slaughter records reported by each country.

3.1. Sourcing the Information

Countries were ranked based on total milk production averaged over 2016, 2017, and 2018 using information provided by the Food and Agriculture Organization (FAO) [18]. Next, we searched for yearly official statistics publications from the top 21st high milk- producing countries regarding the total number of dairy cows, total milk production (kg), average milk yield per animal (kg), and the number of slaughtered cows. For countries that did not officially report average milk yield, this was estimated by dividing the reported total milk production over the number of dairy cows. References and official sources are available upon request from the corresponding author.

A proxy for country level culling rate was obtained by dividing the number of dairy cows slaughtered per year by the total number of dairy cows in each year for the countries from which we were able to find both sets of information. For countries that did not specify the number of dairy cows slaughtered, we used the number of cows slaughtered. The inverse of the culling rate was then used as an estimation of the length of productive life [6,17]. Two criteria were used in data cleaning to define its sufficiency and reliability, respectively. First, only countries with information for at least two consecutive decades were used for further steps. Next, countries in which length of productive life was lower than 1.5 years in earlier decades or greater than 7 years in recent decades were considered unreliable and excluded. After cleaning, information from 10 countries remained.

Linear regression was used to describe the trend over time in both milk yield and length of productive life.

The following polynomial regression model was used to describe both trends:

$$Y_j = \beta_0 + \beta_1 Year_j + \varepsilon_j, \tag{1}$$

in which Y_j represented the milk yield per animal (kg) or length of productive life (year), $\beta0$ was the intercept, $\beta1$ was the linear regression coefficient, $Year_j$ was the value observed in the jth year and εj was the residual error ~ N (0, σ^2). Statistical significance level was set at $\alpha < 0.05$.

3.2. Milk Yield and Longevity over Time

The average milk yield per animal per year increased in all the countries considered in this review. However, the magnitude of the increase was not the same across countries. The estimated increase ranged from 18.5 kg (Standard error; SE = 1.49) per animal per year in Brazil to 129.7 kg (SE = 1.20) kg in the United States, both from 1961 to 2018 (Table 1).

In order to look at the relationship between milk yield and longevity, the differences in production systems need to be considered since not every country uses the same system. For instance, most herds in New Zealand are under a low input pasture-based system while in Canada and the Netherlands cows are typically housed indoors. The average milk yield per animal in New Zealand in 2018 was 2.3 and 2.1 times lower than in Canada and the Netherlands, respectively (Table 1), which was expected since milk yield in a pasture-based system is usually lower compared to indoor-housed systems. The opposite was observed for longevity between these countries. In the 2010s, the average length of productive life in New Zealand was 2.5 and 1.5 times higher compared to Canada and the Netherlands, respectively (Table 2).

Table 1. The linear trend of milk yield (kg) per animal per year for each country between 1961 and 2018. The list of countries is limited to the world's top high milk-producing countries for which we were able to provide sufficient and reliable data on the length of productive life.

Country	Model [1]		R^2 [3]	RSE [4]	*p*-Value [5]
	Intercept [2]	Year [2]			
United States of America	2941.6 *** (40.6)	129.7 *** (1.20)	0.99	152.5	<0.001
Brazil	451.2 *** (50.4)	18.5 *** (1.49)	0.73	189.5	<0.001
Germany	2904.6 *** (83.4)	81.4 *** (2.46)	0.95	313.4	<0.001
France	2103.8 *** (56.8)	91.9 *** (1.68)	0.98	213.6	<0.001
New Zealand	2419.1 *** (70.9)	29.0 *** (2.09)	0.77	266.7	<0.001
Italy	2200.5 *** (91.3)	72.5 *** (2.69)	0.93	343.1	<0.001
Poland	1603.6 *** (107.4)	65.3 *** (3.17)	0.88	403.8	<0.001
Netherlands	3485.8 *** (61.2)	84.3 *** (1.80)	0.97	230.0	<0.001
Canada	2081.3 *** (84.1)	120.7 *** (2.48)	0.98	316.3	<0.001
Ireland	2035.0 *** (53.3)	59.9 *** (1.57)	0.96	200.5	<0.001

[1] *** = *p*-value < 0.01; [2] Estimate (Standard error); [3] R^2 = Coefficient of determination; [4] RSE = Residual standard error; [5] Model significance.

Table 2. The linear trend of the length of productive life (year) in each country. The list of countries is limited to the world's top high milk-producing countries for which we were able to provide sufficient and reliable data on the length of productive life.

Country	Year	Model [1]		R^2 [3]	RSE [4]	*p*-Value [5]
		Intercept [2]	Year [2]			
United States of America	1980–2019	3.25 *** (0.10)	0.0004 NS (0.004)	0.0003	0.30	0.92
Brazil	1997–2018	4.06 *** (0.24)	−0.12 *** (0.02)	0.67	0.55	<0.001
Germany	1993–2019	3.11 *** (0.07)	0.01 NS (0.004)	0.13	0.18	0.06
France	1968–2019	3.89 *** (0.10)	−0.04 *** (0.003)	0.76	0.37	<0.001
New Zealand	1982–2019	3.69 *** (0.19)	0.05 *** (0.01)	0.48	0.56	<0.001
Italy	1970–2019	4.26 *** (0.14)	−0.02 *** (0.005)	0.22	0.49	<0.001
Poland	2003–2019	6.81 *** (0.25)	−0.19 *** (0.02)	0.79	0.50	<0.001
Netherlands	1970–2019	3.38 *** (0.17)	−0.01 NS (0.01)	0.05	0.59	0.12
Canada	1967–2019	3.38 *** (0.13)	−0.03 *** (0.004)	0.57	0.47	<0.001
Ireland	1974–2019	4.28 *** (0.21)	−0.02 * (0.01)	0.14	0.70	0.01

[1] NS = Not significant, * = *p*-value < 0.10, *** = *p*-value < 0.01; [2] Estimate (Standard error); [3] R^2 = Coefficient of determination; [4] RSE = Residual standard error; [5] Model significance.

Differences in production systems could be associated with the longevity status of the animals in different countries. Indoor housing and high input milk production systems are two of the main characteristics shared by most of the high milk-producing countries in this review in which the length of productive life decreased over time. In turn, these are also two of the main differences compared to the production system in New Zealand, where the length of productive life increased. Even though a comparison between systems regarding their effect on the main involuntary culling reasons (reproduction, mastitis, and feet and leg problems) would be inevitably confounded by milk production and animal characteristics between countries even within the same breed, it could be a starting point in exploring the reasons underlying such differences in longevity between countries.

4. A More Comprehensive Definition of Cow Longevity

Contrarily to milk and milk components, dairy cow longevity is neither routinely measured nor reported. This could be partly justified by the lack of a sound definition of the term and, as a result, the nonexistence of a standard metric designed to cover all aspects outlined by such definition. The definition of cow longevity should take into account the health, reproductive performance, and milk production of a dairy animal during its entire lifespan, which in turn are key factors associated with culling [9–11] and the profitability of the dairy industry [7,17]. As much as possible, the definition should allow for the use of metrics that are already routinely collected from either farms or DHI agencies, making it easy to be implemented and to increase the chances of being widely adopted. To that end, dairy cow longevity could be defined as an animal having an early age at first calving and a long productive life spent under profitable levels of milk production. This definition would cover both early life conditions and the stayability of the animal once it reaches the lactating herd, as well as its overall health and quality of life. Age at first calving, length of productive life, and margin over all costs are metrics that could be used as indicators of early life conditions, length of life, and profitability, respectively. Combined, they would provide a more comprehensive approach to measure dairy cow longevity (Figure 1).

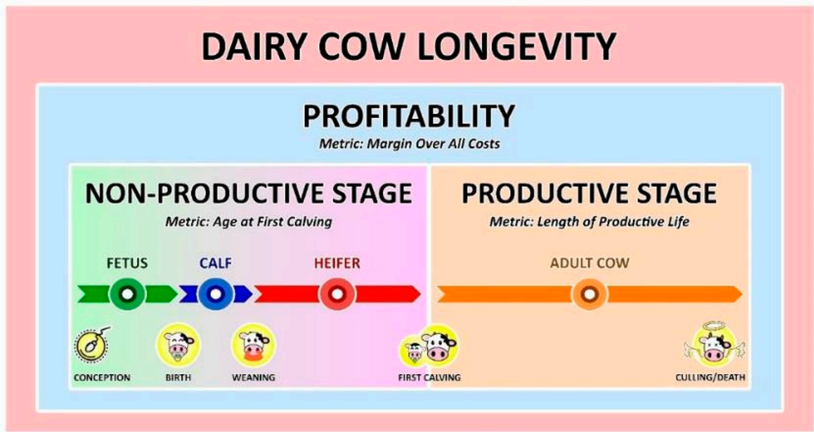

Figure 1. Relationship between profitability, non-productive, and productive life stages of dairy cows for a more comprehensive definition of cow longevity along with proposed metrics representing each respective concept.

5. Conclusions

The current metrics available to measure longevity often start at the first lactation, overlooking early life management practices and decisions made by the dairy farmer before that point. To overcome such limitation, first, we propose that dairy cow longevity should be defined as an animal having an early age at first calving and a long productive life spent under profitable levels of milk production. Next, a combination of the metrics age at first calving, length of productive life, and margin over all (available) costs would provide a more comprehensive evaluation of longevity and cover all aspects of the definition.

By using a standard methodology, this critical literature review confirms the concerns raised by the dairy industry and other stakeholders that dairy cow longevity has decreased in most high milk-producing countries. Early life indicators are needed to support farmers in the early selection of animals that are more likely to reach their maximum potential. Increasing cow longevity due to a reduction in involuntary culling would reduce health costs, increase cow lifetime profitability, improve animal welfare and quality of life, and contribute towards a more sustainable dairy industry by producing milk with inherited sustainability while optimizing dairy farmers' efficiency in the use of resources.

Data Availability Statement: The data used in this study are available from the corresponding author, G.M.D.

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