Animal 20 (2026) 101842

Contents lists available at ScienceDirect

Animal

The international journal of animal biosciences

Effects of productive lifespan on phenotypic lifetime daily milk yield in dairy cows: conclusions from 20-year herdbook data analysis

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ARTICLE INFO

Article history:
Received 13 December 2024
Revised 23 April 2026
Accepted 24 April 2026
Available online 30 April 2026

Keywords:
Animal welfare
Culling reasons
Longevity
Production potential
Survival

ABSTRACT

Although the productive lifespan is a key factor for the sustainability of dairy farming, it has decreased in European countries over many years. We aimed to study the development of production level (2.22 million cows) and productive lifespan (2.31 million cows) from 1999 to 2019 by analysing Swiss herdbook data of Holstein cows (from two different herdbooks: **HO_HOS** from Holstein Switzerland, **HO_SHB** from swissherdbook), Swiss Fleckvieh (**SF**), Brown Swiss (**BS**), Simmental (**SI**) and Original Braunvieh (**OB**) breeds, as well as culling reasons (limited to the period from 2008 to 2019, n = 149 033). Average lifetime daily milk yield (**LDMY**, kg) continuously increased in all breeds studied: in 1999, it ranged from 6.4 ± 3.6 kg/d (SI) to 8.5 ± 4.0 kg/d (HO_HOS), while until 2019, it had significantly increased to values between 7.6 ± 4.1 (SI) and 12.1 ± 5.5 (HO_HOS) kg/d. Contrary to the prevailing European trend, average productive lifespan (**PL**, years) increased significantly (and stabilised) in all breeds except OB from 1999 to 2019: in 1999, it ranged between 1.9 ± 1.7 (HO_SHB) and 3.5 ± 2.7 years (BS), and increased to a range between 3.0 ± 2.1 (HO_HOS) and 3.8 ± 2.8 years (SF) in 2019. In contrast, PL in OB decreased from 4.6 ± 3.3 to 3.6 ± 2.8 years over the same period. Culling rates until the second lactation ranged from 40% (SF) to 51% (HO_SHB). For specialised dairy breeds, fertility and udder health problems were the main culling reasons, while insufficient milk production was more relevant in the dual-purpose breeds OB and SI. Long-living cows were characterised by a lower average milk yield in first lactations, a slower average milk yield increase across subsequent lactations, lower average somatic cell counts and shorter calving intervals. An increase in LDMY through extended PL was most pronounced in early lactations but persisted beyond the 10th lactation in all breeds. When comparing the development of LDMY over 20 years with differences in LDMY among cows culled at different lactations, it becomes evident that the phenotypic increase in LDMY observed over the past two decades is comparable in magnitude to the increase achievable by extending PL of young cows by approximately two lactations, regardless of the breed considered. We conclude that increasing the proportion of mature cows within the herd could yield substantial improvements in the economic and ecological efficiency of dairy production.

Implications

Productive lifespan of dairy cows is often shorter than their physiological potential, with implications for efficiency, sustainability and welfare. This study examined how extending productive lifespan influences lifetime daily milk yield using long-term herdbook data. Results indicate that extending the productive lifespan of young cows by approximately two lactations, especially in specialised dairy breeds, could increase average lifetime daily milk yields to a level comparable to the realised phenotypic gains observed over 20 years. Lifetime daily productivity can be enhanced by reducing the high culling rates in early life therewith increasing the proportion of mature cows in herds.

Introduction

Productive lifespan is a key factor for the sustainability of dairy farming. A long productive lifespan amortises rearing costs over a longer period of time (Bergeå et al., 2016; Grandl et al., 2019) and reduces replacement costs (Horn et al., 2012). Moreover, the resource consumption and emissions of rearing, including greenhouse gas emissions, are distributed over more days in milk with increased productive lifespan (Grandl et al., 2019).

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https://doi.org/10.1016/j.animal.2026.101842
1751-7311/

The natural life expectancy of cows is up to 20 years (Hoffman and Valencak, 2020), but the vast majority of dairy cows lives considerably shorter due to culling decisions of the farmer (Fetrow et al., 2006). Productive lifespan of dairy cows has been reported to be declining across different countries for many years (Olechnowicz et al., 2016; De Vries, 2020; Schuster et al., 2020; Dallago et al., 2021). This is partly associated with the simultaneous and pronounced increase in milk yield realised over the past decades (Knaus, 2009). Depending on the source, longevity defined as time from birth until culling is described as ranging between 4.5 and 5.5 (Knaus, 2009; Schuster et al., 2020) or 4.5 and 6 years (De Vries, 2020; De Vries and Marcondes, 2020), which corresponds to 2.4 and 3.6 lactations (Schuster et al., 2020). Average productive lifespan of 2.5–4 years is reported for countries with high-producing dairy cows (De Vries and Marcondes, 2020).

This is far below the physiological potential of cows and supports the view that high yields in individual early lactations may be achieved at the expense of animal longevity (Knaus, 2009; Bieber et al., 2019). The causal reasons are manifold, ranging from limits of physiology to compliance with breeding schemes (De Vries and Marcondes, 2020; Schuster et al., 2020) and from farm economies to social drivers and barriers (Rödiger and Home, 2023). If cows are culled early for voluntary culling reasons like milk yield, this is not primarily linked with animal health and welfare. However, low yield may in some cases reflect underlying or previous health and welfare problems that are not explicitly recorded as the primary culling reason. By contrast, involuntary culling reasons like infections, lameness, infertility or metabolic diseases may well be a matter of ethical concern (Fetrow et al., 2006; Schuster et al., 2020).

Whatever the reasons for short productive lifespan are, it is also important to look at the effects. Resource efficiency is often used as an argument for the target of increasing yields in early lactations, but one may argue that true efficiency must include the rearing phase and thus be expressed through days lived, feed consumed, emissions released and space occupied through all days of life (Schader et al., 2015; Ledinek et al., 2022). Therefore, the average amount of milk produced per day of life is also relevant for any measure of efficiency and should be considered when characterising the productivity of dairy cows (Dallago et al., 2021).

Long-term herdbook data provide a valuable basis for describing trends in productive lifespan, lifetime milk yield, and culling patterns at the breed level over extended periods. Such data allow for a comprehensive understanding of how these parameters develop over time and their implications for dairy cow productivity.

In this light, our study of a 20-year dataset containing Swiss herdbook dairy cows focused on four questions related to the productive lifespan using descriptive statistics, trend analyses, complemented by inferential statistical methods: (i) what is the impact of productive lifespan on phenotypic milk yield if calculated as average per day of life, (ii) when are dairy cows mainly culled and what are the main culling reasons, (iii) how do cows with different productive lifespan differ in terms of milk yield, udder health and fertility, and (iv) in which phase of productive life do culling decisions have the largest impact on lifetime daily milk yield and therefore require the greatest attention.

Material and methods

Data origin

For this study, herdbook data of dairy cows from the breeding organisations Braunvieh Schweiz (BVCH, Zug, Switzerland), swissherdbook (**shb**, Zollikofen, Switzerland) and Holstein Switzerland (**HOS**, Posieux, Switzerland) were provided by the competence centre for informatics and genetics of Swiss breeding organisations, Qualitas AG (Zug, Switzerland), including culling reasons originating from the animal tracing database (Tierverkehrsdatenbank) run by Identitas AG (Bern, Switzerland) on behalf of the Federal Office for Agriculture (Bern, Switzerland). Data from all lactations of dairy cows with calvings from 1 January 1999 to 31 August 2019 and an existing culling date were selected, resulting in a data set of 2.6 million dairy cows, 8.13 million lactations.

Breed definitions

Within the Brown Cattle population in Switzerland, we differentiated between the Original Braunvieh (**OB**) and Brown Swiss (**BS**). The latter are the result of crossbreeding Brown Swiss cattle selected for milk production in the US into the Original Braunvieh population (Hagger, 2005) since the 1970s. The two breeds exhibit clear genetic distance (Signer-Hasler et al., 2017) and have separate herdbook sections.

The Swiss Fleckvieh (**SF**) breed was developed by crossing US Red Holstein (**RH**) genetics into the Simmental breed since the 1970s. Within the Holstein population, the Red Factor (**RF**) marks animals that carry the gene responsible for red coat colour.

In 2000, an interest group (IG SF, https://www.swissfleckvieh.ch/) was founded to promote the SF as a separate breed with a focus on long productive lifespan. As part of the implementation of Switzerland's new 2014 Animal Breeding Ordinance, all SF cows and all RH cows with less than 87.5% Holstein blood born before July 2008 were designated as 100% (purebred) SF and entered their own herdbook (Meier, 2020). Today, average SF cows have approximately 65% Holstein blood and 35% Simmental blood (swissherdbook, 2023). The breed distinction by percentage of Holstein blood between SF and Holstein within the swissherdbook breeding organisation (**HO_SHB**) has changed several times over the past decades (M. Schelling, swissherdbook, personal communication). To ensure comparability for historical data, the current blood percentage limit of at least 87.5% Holstein blood percentage for HO_SHB was applied to all data included in the current study.

The following six breeds were distinguished based on herdbook affiliation (in the case of Holstein cows), blood percentages (Holstein blood in SF, Brown Swiss blood in OB), and breed codes (all cows): Brown Swiss (BS, including the breed codes BS and BV), Original Braunvieh (OB, including cows of the purebred breed OB and cows crossed back to at least 87.5% OB blood, coded as ROB), SF, Holstein from the swissherdbook (HO_SHB, including the breeds RH, HO and RF, Simmental (**SI**, coded with SI or the historical codes 60, 70), and Holstein from the Holstein Switzerland herdbook (**HO_HOS**).

Variables

We obtained records at lactation level with information on animal identification number, farm identification number, date of birth, age at first calving (d), calving date, lactation number (i.e. number of parity), lactation milk yield (kg), fat yield for standard lactation (kg), protein yield for standard lactation (kg), average somatic cell count of lactation (cells/ml milk), and lactation length (days in milk) for the study period (1999–2019). Information on calving interval (d), i.e. number of days between two calving events, was included in records from second parity onwards and was only available for cows with consecutive calving records; thus, observations without a subsequent calving event were not present in the dataset. Average lifetime daily milk yield was calculated on the cow level by dividing lifetime milk yield (sum of all lactations of an individual cow) by its lifetime (i.e. days from date of birth until culling). Herd size was approximated per farm and year by counting the number of calving events per farm during one calendar year.

In the present study, productive lifespan is defined as the time from first calving to exit from milk performance testing in the herdbook through culling. The terms productive lifespan and longevity are used synonymously hereafter.

Data validation and sample size

Data were cleaned using the following thresholds: age at first calving 20–42 months, calving interval 280–750 days, lactation milk yield 2 000–25 000 kg, average daily milk yield 6.6–82 kg, fat yield for standard lactation 60–1 000 kg, protein yield for standard lactation 50–800 kg, somatic cell count 0–9.9 million cells/ml milk, herd size > 2 animals, lactation length up to 720 days, and lactation number 1–20 lactations.

A detailed overview of sample sizes by breed obtained after validation is provided in Table 1.

Culling reasons

Data on culling reasons analysis were limited to the period from 2008 to 2019 and contained a total of 149 033 cow records. The following culling reasons were distinguished in the data delivered: "poor fertility", "udder and/ or teat problem", "claw and/ or leg problem", "insufficient milk yield", "gastrointestinal or metabolic problems", "calving difficulties", "injury or accident" and "other problems". Data were provided by Qualitas AG, its source being the animal tracing database (Tierverkehrsdatenbank), which ensures traceability of livestock in Switzerland via ear tags and is run by Identitas AG (Bern, Switzerland) on behalf of the Swiss Federal Office for Agriculture (Bern, Switzerland).

Data analyses

This study applied a descriptive methodological approach to empirically assess the development of productive lifespan, as well as associated performance and health parameters, over a 20-year period in all major Swiss dairy breeds.

Data were analysed and presented to show both the temporal developments of average lifetime daily milk yield (kg) and average length of productive lifespan (years) from 1999 to 2019, as well as the relationship between the number of lactations at culling (levels 1–11ff) and changes in average lifetime daily milk yield. Data processing and visualisation were conducted using the "tidyverse" package (Wickham et al., 2019) in R (versions 3.6.1, 4.0.3, 4.0.5, R Core Team, 2020).

Lifetime daily milk yield (kg) and length of productive lifespan (years) were analysed from two perspectives. The first perspective focused on temporal trends, with mean values calculated for each year from 1999 to 2019 for lifetime daily milk yield (kg) and productive lifespan (years) based on cow-level data for each breed separately. A linear regression model proposed by Dallago et al. (2021) was applied to describe temporal trends:

$$Y_j = \beta_0 + \beta_1 \text{Year}_j + \varepsilon_j,$$

where Y_j represented lifetime milk yield (kg) or length of productive life (years) at the cow level, β_0 was the intercept, β_1 was the linear regression coefficient, Year_j was the value observed in the j^{th} year (levels: 1999–2019) and ε_j was the residual error.

Additionally, the median values for lifetime daily milk yield (kg) and length of productive life (years) in 1999 and 2019 were compared within each breed using Wilcoxon-Mann-Whitney tests implemented in the "rstatix" package (Kassambara, 2023). This non-parametric test was chosen because visual inspection indicated deviation from normality for both variables.

Statistical significance for models and tests was defined as $P < 0.05$.

The second perspective described mean values of lifetime daily milk yield (kg) derived from cow-level data in relation to the lactation number at culling, providing descriptive insights into how lifetime daily milk yield changes with the lactation number at culling.

Finally, these two perspectives were combined by presenting the average lifetime daily milk yield (with SDs) by lactation number at culling, alongside temporal development. Specifically, this combined overview includes the average productive lifespan and average lifetime daily milk yield (with SDs) for the years 1999 and 2019, based on cow-level data.

Culling rates and reasons for culling were calculated based on cow-level data and are presented as proportions (%) by breed. Average culling rates are shown by lactation number (levels 1–10ff) within each breed.

Finally, lactation-level data (1999–2019) were used to describe the development of average lactation milk yield by lactation number within breeds, identifying the lactation in which cows achieve their maximum lactation milk yield.

Results

Milk yield development

Lifetime daily milk yield of cows by year of culling increased continuously for all breeds over the 20-year study period (Fig. 1). Year had a significant effect on this trait across all breeds (Table S1 in the Supplementary material). In 2019, HO_HOS cows exhibited the numerically highest average lifetime daily milk yield (12.1 ± 5.5 kg) and SI cows the lowest (7.6 ± 4.1 kg), with HO_SHB (11.0 ± 5.2 kg), BS (10.2 ± 4.7 kg), SF (10.2 ± 5.0 kg) and OB (8.1 ± 4.2 kg) ranging in between.

Development of longevity

Average productive lifespan increased from 1999 to 2019 in all breeds studied, with the exception of OB, for which it decreased (Fig. 2). Year had a significant effect on this trait across all breeds (Table S2 in the Supplementary material). The changes in average productive lifespan (years) from 1999 to 2019 were as follows: in OB cows, it declined from 4.6 years (± 3.3 SD) in 1999 to 3.6 years (± 2.8 SD) in 2019 ($P < 0.001$); in SF cows, it increased from 2.8 years (± 2.4 SD) to 3.8 years (± 2.8 SD) ($P < 0.0001$); in BS cows, from 3.5 years (± 2.7 SD) to 3.7 years (± 2.7 SD) ($P < 0.0001$); in SI cows, from 3.1 years (± 2.7 SD) to 3.3 years (± 2.7 SD) ($P < 0.0001$); in HO_SHB cows, from 1.9 years (±1.7 SD) to 3.1 years (± 2.3 SD)

Table 1
Overview of sample sizes (number of cows and lactations) by dairy cattle breed from 1999 to 2019, obtained after data validation.

	Sample size	
Breed[1]	Cows	Lactations
HO_HOS	262 359	704 236
HO_SHB	497 467	1 407 379
SF	652 299	2 128 307
BS	1 011 192	3 294 410
OB	50 063	173 030
SI	128 920	426 352
Sum	2 602 300	8 133 714

[1] HO_HOS = Holstein from the Holstein Switzerland herdbook, HO_SHB = Holstein from the swissherdbook, SF = Swiss Fleckvieh, BS = Brown Swiss, OB = Original Braunvieh, SI = Simmental.

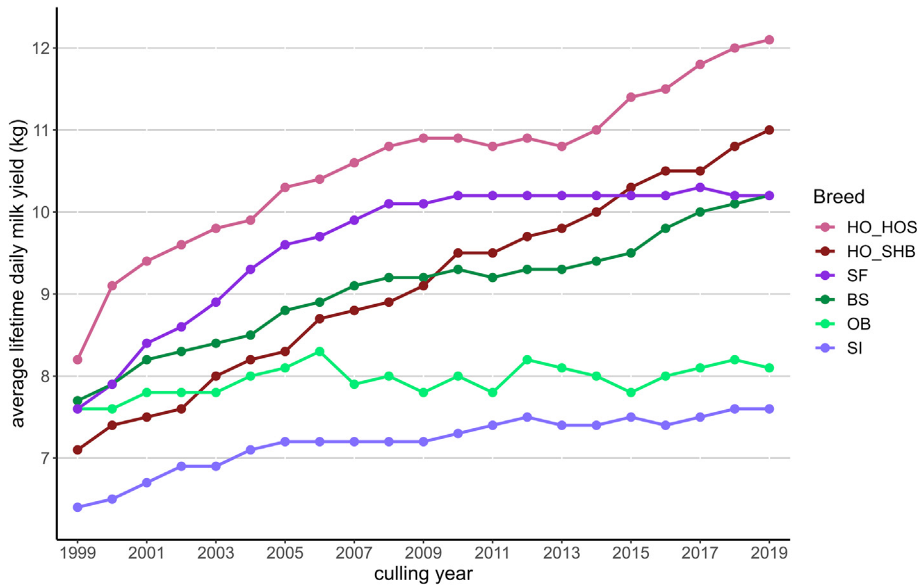

Fig. 1. Development of average lifetime daily milk yield (kg) by dairy cattle breed and year of culling from 1999 to 2019. Footnote: Total sample sizes across the study period (1999–2019): HO_HOS = Holstein from the Holstein Switzerland herdbook, n = 223 667; HO_SHB = Holstein from the swissherdbook, n = 381 946; SF = Swiss Fleckvieh, n = 602 473; BS = Brown Swiss, n = 866 318; OB = Original Braunvieh, n = 36 385; SI = Simmental, n = 108 792.

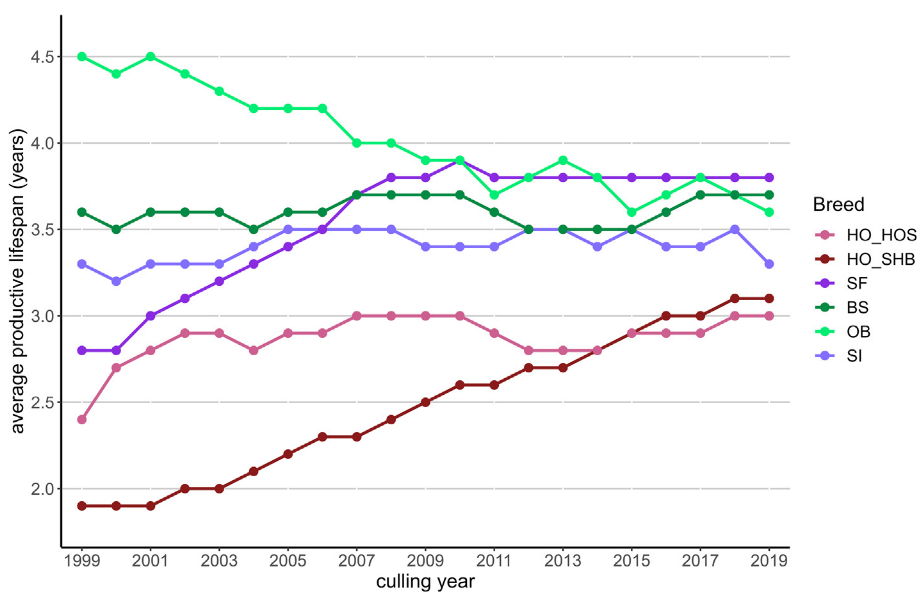

Fig. 2. Development of average productive lifespan (years) by dairy cattle breed and year of culling from 1999 to 2019. Footnote: Total sample sizes across the study period (1999–2019): HO_HOS = Holstein from the Holstein Switzerland herdbook, n = 223 667; HO_SHB = Holstein from the swissherdbook, n = 401 294; SF = Swiss Fleckvieh, n = 616 872; BS = Brown Swiss, n = 921 896, OB = Original Braunvieh, n = 39 336; SI = Simmental, n = 113 793.

($P < 0.0001$); and in HO_HOS cows, from 2.5 years (± 1.8 SD) to 3.0 years (± 2.1 SD) ($P < 0.0001$).

Linking average daily milk yield and longevity

Average lifetime daily milk yield increased with each successive lactation (solid lines for all six breeds in Fig. 3) and was highest in cows culled in 11th lactation or later. In the 11th lactation and beyond, the yields were numerically highest in HO_SHB cows (18.7 kg/day of life), followed by HO_HOS (18.0 kg/day of life), SF (15.9 kg/day of life), BS (14.7 kg/day of life), while OB and SI cows showed the lowest yields (12.9 kg/day of life for both breeds).

The numerically largest increases in average lifetime daily milk yield were observed in early lactations. The increase (delta) from the first to the second lactation and from the second to the third lactation was highest in HO_HOS cows (4.8 kg and 2.9 kg, respectively) and HO_SHB cows (4.6 kg and 2.9 kg, respectively). These were followed by BS (3.7 kg and 2.4 kg), SF (3.7 kg and 2.5 kg), SI (3.2 kg and 2.0 kg), and OB cows (3.1 kg and 2.1 kg).

The overall increase in average lifetime daily milk yield from 1999 to 2019 (represented by squares in the upper right of Fig. 3, with lighter colours for 1999 and darker colours for 2019) was significant in all breeds. The largest increase was observed in HO_SHB (+3.8 kg milk/day of life, $P < 0.0001$), followed by HO_HOS (+3.6 kg milk/day of life, $P < 0.0001$), SF

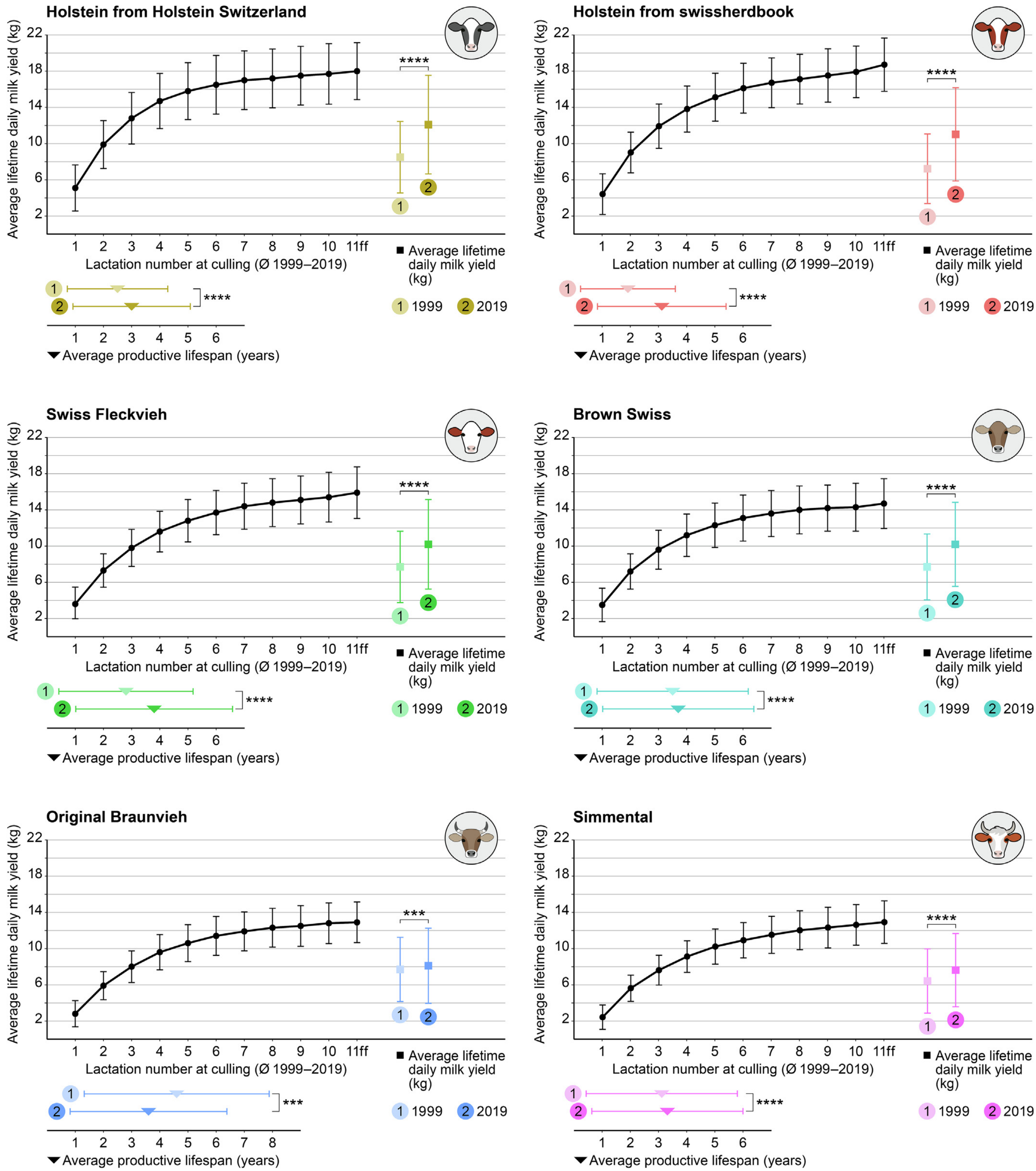

Fig. 3. Lifetime daily milk yield achievable through increase in productive lifespan in relation to increase in average lifetime daily milk yields from 1999 to 2019 in six Swiss dairy cattle breeds. Footnote: ◯ Dots connected by solid lines represent average lifetime daily milk yield (kg) by different lactations at culling. ◻ Squares in the top right of the figures represent average lifetime daily milk yield (kg) for 1999 (lighter colours) and 2019 (darker colours). △ Triangles at the bottom of the figure below the first x-axis represent average productive lifespan (years) for 1999 (lighter colours) and 2019 (darker colours). Bars across all three variables represent SDs. ***$P < 0.001$, ****$P < 0.0001$, P-values for comparisons of values in years 1999 and 2019 are derived from Wilcoxon-Mann-Whitney tests. Sample sizes by breed and lactation are provided in Supplementary material Table S3.

(+2.5 kg milk/day of life, $P < 0.0001$), BS (+2.4 kg milk/day of life, $P < 0.0001$), SI (+1.2 kg milk/day of life, $P < 0.0001$) and OB (+0.4 kg milk/day of life, $P < 0.001$), respectively.

Average productive lifespan (represented by triangles below the first X-axis of Fig. 3, with lighter colours for 1999 and darker colours for 2019) also increased from 1999 to 2019 in most breeds.

Increases of 1.2 years in HO_SHB, 1.0 years in SF, 0.5 years in HO_HOS, and 0.2 years in both BS and SI cows were observed ($P < 0.0001$ for all breeds). In contrast, average productive lifespan decreased by 1 year in OB cows over the same period ($P < 0.001$).

Culling frequency and reasons

The average lactation numbers at culling by breed for cows between 1999 and 2019 are shown in Fig. 4. Most cows were already slaughtered in the first lactation, closely followed by high slaughter rates in the second lactation. The average percentage of slaughtered cows varied between breeds and ranged from 21.4% (SF) to 27.1% (HO_SHB) in first lactation and between 17.5% (OB) and 24.0% (HO_SHB) in second lactation. Consequently, the average percentage of culled cows within the first two lactations ranged between 39.8% (SF) and 51.1% (HO_SHB).

An overview of the main culling reasons, summarised over the period from 2008 to 2019, is presented in Table 2. Fertility problems were the main culling reason in all six breeds studied, ranging from 23% to almost 36% of culling events, followed by udder and teat diseases. The exception was SI, where insufficient milk yield ranked second, and udder and teat problems ranked as the third most common culling reason. The third most common culling reason differed by breed: While leg and claw problems ranked third in BS and HO_SHB, other problems were more frequent by 0.1% in SF and HO_HOS, and insufficient milk yield ranked third for OB.

Summarised, fertility problems, udder health problems and problems with claws or legs accounted for 51–70% of culling events, i.e. for 70% in HO_SHB, 68% in BS, 66% in HO_HOS, 65% in SF, 64% OB and 51% in SI, respectively.

Differences in key traits by lactation number reached

Long-living cows exhibited a numerically lower average lactation milk yield in first lactations and were characterised by a slower average milk yield increase to the next lactation. This pattern was observed in all breeds, although on different scales, i.e. Holstein breeds showing the highest and SI showing the lowest average milk yields (Supplementary Figure S1). The highest average lactation milk yield was observed in 4th lactation for HO_HOS and in 5th lactation for all other breeds (Fig. 5). Average lactation milk yield remained constant for at least two more lactations until it started to slightly drop again (Fig. 5).

Moreover, long-living cows exhibited numerically lower average somatic cell counts at lactation level and a slower increase of this parameter throughout life (Supplementary Figure S2). Finally, long-living cows were characterised by a numerically shorter average calving interval, i.e. better fertility performance (Supplementary Figure S3).

A marked increase in average somatic cell count, indicating udder health problems, was observed in the last lactation. A numerical increase in the calving interval was also observed in the lactation preceding culling.

Discussion

Milk yield development

The milk yield increase over the past decades found in our study aligns with reports from other countries (e.g. Knaus, 2009; Schuster et al., 2020; Dallago et al., 2021). However, the magnitude of this increase is lower level compared to high-producing countries such as the United States, Denmark and Canada (Schuster et al., 2020). Dallago et al. (2021) point out that the differences in milk yield increases between countries over the past decades may be closely linked to feeding systems. Most of the countries studied by Dallago et al. (2021) were characterised by large increases in milk yield and a decline in productive lifespan between 1961 and 2018, primarily under indoor housing systems. In contrast, New Zealand, where low-input, grassland-based feeding systems dominate, exhibited milk yields that were 2.3 to 2.1 times lower than those in Canada and the Netherlands, while

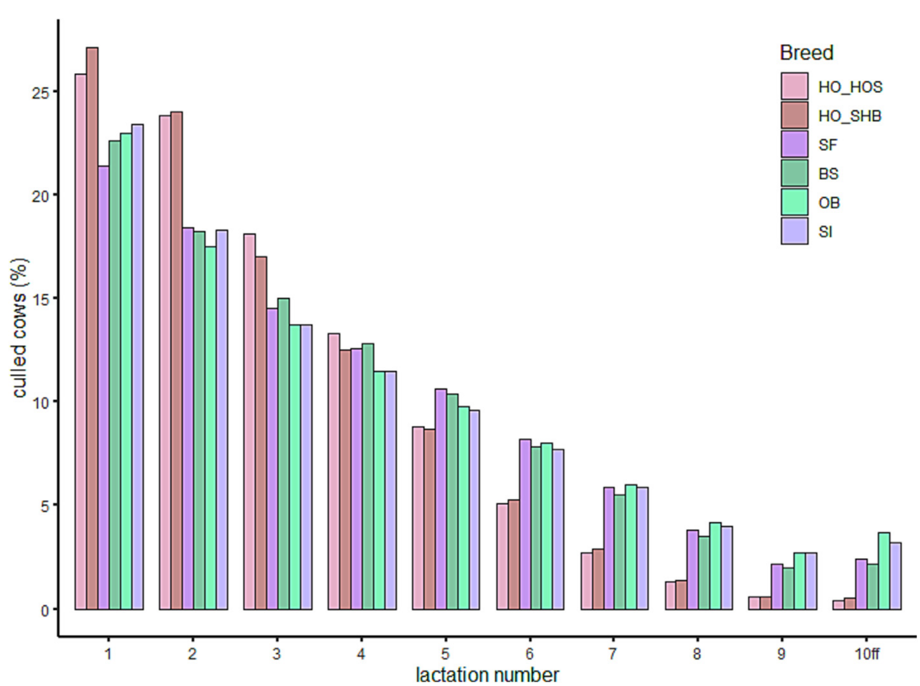

Fig. 4. Average culling rates by lactation number and breed of cows being culled between 1999 and 2019. Footnote: HO_HOS = Holstein from the Holstein Switzerland herdbook, n = 262 359; HO_SHB = Holstein from the swissherdbook, n = 497 467; SF = Swiss Fleckvieh, n = 652 540; BS = Brown Swiss, n = 1 044 157; OB = Original Braunvieh, n = 52 308; SI = Simmental, n = 128 967. ff = and the following (i.e., values equal to and greater than the indicated number).

Table 2
Culling reasons (in %) in six dairy cattle breeds, including sample size (n) and proportion of records with available culling information (%) relative to the total number of cows per breed, from 2008 to 2019, as reported in the animal tracing database in Switzerland (Tierverkehrsdatenbank, Bern).

Culling reason	Breed[1] including sample size and proportion of records with available culling information (%) relative to the total number of cows per breed[2]					
	HO_HOS	HO_SHB	SF	BS	OB	SI
	n = 14 016 8.8%	n = 39 010 12.2%	n = 33 826 11.7%	n = 56 807 11.4%	n = 1 675 6.8%	n = 3 699 5.6%
Fertility problem	32.1	35.7	31.6	30.6	32.9	23.1
Udder or teat problem	22.8	23.8	21.7	22.7	18.0	17.6
Claw or leg problem	10.8	10.7	11.7	15.1	13.4	10.7
Insufficient milk yield	6.4	6.9	8.8	11.6	13.6	19.7
Gastrointestinal or metabolic problem	4.7	4.1	3.5	3.0	2.0	2.1
Calving difficulties	4.5	4.5	5.4	5.4	5.5	5.0
Other problem	10.9	8.4	11.8	7.5	9.2	17.5
Accident or injury	7.8	5.9	5.5	4.1	5.4	4.3

[1] Breeds: HO_HOS = Holstein from the Holstein Switzerland herdbook, HO_SHB = Holstein from the swissherdbook, SF = Swiss Fleckvieh, BS = Brown Swiss, OB = Original Braunvieh, SI = Simmental.
[2] Number of total cows per breed from 2008 to 2019: HO_HOS = 159 273, HO_SHB = 319 754, SF = 289 111, BS = 498 307, OB = 24 632, SI = 66 054.

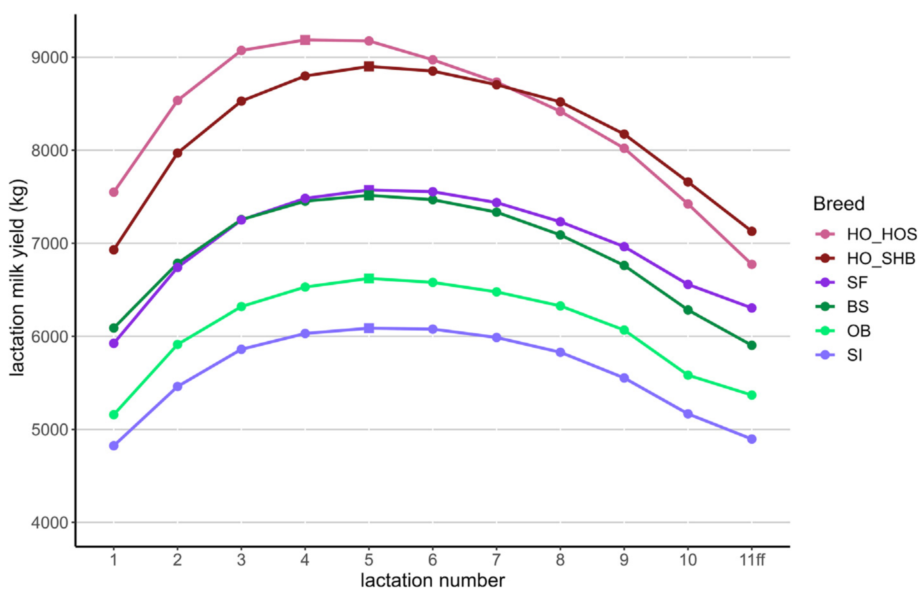

Fig. 5. In which lactation do cows reach their highest average lactation milk yield?. Footnote: Squares represent the highest lactation performance for each breed[1]. [1]Breeds: HO_HOS = Holstein from the Holstein Switzerland herdbook, HO_SHB = Holstein from the swissherdbook, SF = Swiss Fleckvieh, BS = Brown Swiss, OB = Original Braunvieh, SI = Simmental. Sample sizes by breed and lactation number are provided in Supplementary material Table S4. ff = and the following (i.e., values equal to and greater than the indicated number).

increases in productive lifespan were 2.5 to 1.5 times higher compared to Canada and the Netherlands (Dallago et al., 2021). We assume that Swiss dairy production is characterised by comparably high proportions of grassland-based feeding, which explains the moderate milk yield level compared to other countries described by Schuster et al. (2020) and Dallago et al. (2021).

As expected, milk yield increase was less pronounced in the dual-purpose breeds SI and OB, explainable by genetic antagonisms between milk yield and beef production traits (e.g. Mancin et al., 2021).

Development of longevity

With an average of up to 3.8 years in our study, the average productive lifespan is in the upper range or above the values reported for most developed dairy industries (De Vries and Marcondes, 2020; Schuster et al., 2020). Even the shortest-producing Holstein breeds we found in Switzerland had slightly higher average productive lifespan than Holstein cows in the US, the latter reported to be less than 3 years (De Vries and Marcondes, 2020).

Culling risk in primiparous cows was found to be higher than in multiparous cows (Vukasinovic et al., 1997; Olechnowicz et al., 2016). Many studies have reported alarmingly high culling rates of young cows, especially in first lactation (reviewed by Olechnowicz et al., 2016). While Schuster et al. (2020) reported 8–19% culling events in first lactation, Horn et al. (2012) found that 50% of the dairy cows in their study did not complete more than three lactations. In larger US herds with at least 200 cows, 37% of the cows were culled during first lactation and 83% within the first three lactations (De Vries et al., 2010). The finding by Horn et al. (2012) corresponds to the high culling rates we found in first and second lactation across all breeds studied.

The high percentage of cows being culled during first lactation is critical both with regard to environmental footprint per unit of product and in economic terms, as rearing costs are usually not recouped when culling occurs so early (Grandl et al., 2019). The positive effects of a longer productive lifespan on emission reduction are more pronounced in cows with a short productive lifespan, while the effect sizes decrease for medium and long productive lifespans (Grandl et al., 2019). Therefore, it seems advisable to focus on the reduction of high culling rates in early lactations as one building block to improve the environmental impact of dairy production. Moreover, cows with a longer productive lifespan reduce the frequency of replacements, thereby lowering the emissions associated with rearing young stock for herd renewal (van Middelaar et al., 2014). In addition, maturity costs, which account for the fact that cows in the first four lactations produce less milk than mature cows from the fifth lactation onwards, decrease with a longer productive lifespan (De Vries, 2020), thereby potentially improving the economic performance of the herd (Gazzarin et al., 2025).

Exploitation of longevity for a higher daily milk yield

Our analysis of changes in lifetime daily milk yield and average productive lifespan from 1999 to 2019 suggests that the increase in lifetime daily milk yield cannot be attributed solely to genetic progress in milk yield and management improvements over the past years. Rather, it must partly be attributed to the extension of average productive lifespan in all breeds (except for OB), hereby allowing greater exploitation of cows' physiological potential for milk production in later lactations. Additionally, the pronounced inclusion and weighting of functional traits in selection indexes since the 2000 s may have contributed to the observed increase in productive lifespan, while enabling concurrent genetic improvement in milk yield and other functional traits (Miglior et al., 2012; Egger-Danner et al., 2015), despite inherent trade-offs with milk yield (Oltenacu and Broom, 2010; Berry et al., 2014).

From our findings, we conclude that an average increase in productive life of young cows by approximately two lactations is comparable to the increase in lifetime daily milk yield that has been achieved over the last 20 years through breeding progress and management improvements, especially for specialised dairy cow breeds. An analysis of German Holstein population data from the 1980s and 1990s revealed a similar result (Leiber, 2001). As increases in lifetime daily milk yield are most pronounced in early lactations (Mißfeldt et al., 2015; De Vries and Marcondes, 2020), and a high proportion of cows is culled during these early lactations (Olechnowicz et al., 2016; Horn et al., 2012; De Vries et al., 2010), the greatest potential lies in transferring more cows from the first and second lactations into the third to fifth lactations. Therefore, involuntary culling reasons associated with management-related factors need to be addressed.

Reviews state that the economic importance of longevity is also a result of a higher proportion of cows in more profitable lactations (Essl, 1998; Olechnowicz et al., 2016; Schuster et al., 2020). In line with this, an economic evaluation of longevity in Austrian organic dairy cows reported the maximum annual milk yield to be reached in the 5th lactation, and the maximum annual profit in the 6th lactation (Horn et al., 2012). In order to identify the economically optimal productive lifespan, good decision tools are needed for farmers at herd level. These tools should adequately reflect the complex economic implications of longevity in dairy herds (De Vries, 2020). In the case of Switzerland, this tool should also be able to adjust for different production conditions, e.g. in valley and mountainous production zones and the resulting cost differences.

Culling reasons

The sample size for culling reasons was relatively limited in our study. The sparse use of the possibility to indicate culling reasons in the animal tracing database is documented and criticised by Fuss and Burren (2018) for Holstein cows in the HOS herdbook. The situation in Brown Swiss cows is similar, as only 10% of the registered culling events in the animal tracing database indicate a culling reason (Schabana, 2021). Despite the limited sample size, the main culling reasons we found in our study partly match culling reasons reported in the literature and by Swiss herdbook news: matching our data, insufficient fertility has been reported to be the most relevant culling reason (34%) in HO_HOS cows culled between 2008 and 2016 (n = 4 473), followed by teat and udder health problems in second and claw or leg diseases in third place (Fuss and Burren, 2018). German and Canadian data show the same ranking of involuntary culling reasons in the decades from 1980 to 2000 (Leiber, 2001). Likewise, insufficient fertility was the most frequent culling reason in Brown Swiss cows in 2020, i.e. 34% of the indications in the animal tracing database (Schabana, 2021), and mastitis was the second most common culling reason in 2017 (Schabana, 2019). International studies show different rankings of culling reasons in dairy cows, depending on the classification of culling reasons, the inclusion or exclusion of deaths, the breed studied and the production intensity (see reviews by Olechnowicz et al., 2016; De Vries and Marcondes, 2020). However, it can be summarised that fertility problems are the most frequent involuntary culling reason, mostly followed by udder health problems and claw or leg problems (Olechnowicz et al., 2016; De Vries, 2020; Schuster et al., 2020; Dallago et al., 2021). While insufficient milk yield plays an important role as the second or third most frequent culling reason in some studies (Pinedo et al., 2010; Olechnowicz et al., 2016; De Vries, 2020), this was only true for dual-purpose breeds in our study, where milk yield ranked second for SI and third for OB cows. Culling rates for dual-purpose breeds like SI and OB are however also driven by beef demand on the market (Bieber et al., 2025). For high-producing countries, low milk yield as a culling reason is reported to decrease, probably due to successful genetic selection for milk production in the past years (Dallago et al., 2021). In addition, some studies from the US report death and injury to be major culling/disposal reasons (De Vries and Marcondes, 2020).

Incentives for a more complete declaration of culling reasons by (Swiss) dairy farmers are needed, in order to specifically address the most relevant problems adequately and also to open up the possibility to use this information in breeding value estimation of bulls. Moreover, a reliable quantification of the proportion of involuntary culling events could be used as an animal welfare indicator at the herd level (Ahlman et al., 2011). Addressing the causes of involuntary culling would support a shift from forced to economic culling, thereby improving welfare (Schuster et al., 2020).

Characteristics of long-living cows

Our findings of lower milk yields, particularly in early lactations and a slower milk yield progression in long-living cows, are consistent with results from a comparison of German Holstein cows classified as exceptionally long-living (>9 lactations) with their contemporary herdmates, which showed significantly lower milk yields in the first three lactations and more favourable somatic cell score characteristics (Abfalter et al., 2016).

These results suggest that overly strict selection against low-yielding cows in the first and second lactation that are otherwise healthy should be avoided. High milk yields are associated with a more pronounced negative energy balance, which contributes to immunosuppression during the periparturient period, thereby increasing the risk of digestive, metabolic and infectious problems (e.g. reviewed by Ingvartsen and Moyes, 2013). Accordingly, high milk yield is associated with negative effects on health, fertility and longevity (e.g. Knaus, 2009; Oltenacu and Broom, 2010; De

Vries and Marcondes, 2020). A direct impact of milk yield on longevity has been studied by Haworth et al. (2008), who reported that Holstein cows producing more than 30 l/day in North Queensland Australia, did not survive more than two lactations. However, some studies report a reduced culling risk for higher–yielding cows at the individual animal level (De Vries and Marcondes, 2020).

In view of the main culling reasons - fertility and udder health problems - it is not surprising that long-living cows were found to have a shorter calving interval and lower mean lactation cell counts. In line with our results, the literature also states that both health and fertility make cows economically promising and reduce the probability of involuntary culling (Essl, 1998).

Conclusions

Contrary to international studies reporting a decline in productive lifespan in dairy cows, we observed an increase in productive lifespan over a 20-year period in five of the six Swiss breeds studied. Therefore, we conclude that part of the phenotypic increase in average lifetime daily milk yield over this period can be attributed to longer productive lifespan. Our findings suggest that increasing the productive lifespan of young cows by approximately two lactations could achieve a gain in average lifetime daily milk yield comparable to the overall increase observed over the past 20 years studied. Reducing high culling rates, especially in first and second lactations, is a key to further exploiting the physiological potential of healthy dairy cows to increase milk yield in subsequent lactations, thereby potentially improving both the ecological and economic performance of dairy herds. However, the high incidence of involuntary culling reasons in specialised dairy-type breeds may indicate welfare issues associated with high-yield production systems.

From an empirical perspective, cows with a long productive lifespan were characterised, among other factors, by lower milk yield in first lactation. This suggests that farmers should be patient with lower-yielding young cows if they are otherwise healthy and fertile, and focus on increasing the proportion of mature cows in their herds. Incentives to increase the reporting of culling reasons are needed to improve data reliability, which would allow better identification of the most relevant challenges and the use of such information for breeding value estimation. Moreover, economic evaluation tools should be developed to assist farmers in defining optimal productive lifespans under differing economic and environmental production conditions.

Supplementary material

Supplementary Material for this article (https://doi.org/10.1016/j.animal.2026.101842) can be found at the foot of the online page, in the Appendix section.

Ethics approval

There was no need to obtain ethics approval for analysis and publication of the anonymised herdbook data used in this study.

Data and model availability statement

Restrictions apply to the availability of these data, which were used exclusively for this study and remain the property of the providing organisation Qualitas AG (Zug, Switzerland), where the data would be available upon reasonable request and on the basis of data use agreements. Information can be made available from the authors upon request.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) did not use any AI and AI-assisted technologies.

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Declaration of interest

The authors have not stated any conflicts of interest.

Acknowledgements

We gratefully acknowledge the support of Urs Schnyder (Qualitas AG, Zug) in data provision and Lucas Casanova (Braunvieh CH, Zug), Michel Geinoz (Holstein Switzerland, Posieux), Matthias Schelling (swissherdbook, Zollikofen) and Urs Schnyder (Qualitas AG, Zug) for their support in data interpretation and historical background to the development of breeds. We would like to thank our colleagues, Sandra Walti, for designing the breed icons and Brigitta Maurer for preparing Fig. 3 and editing the figures in the Supplementary material.

Financial support statement

This study was realised within the project "Increasing the productive lifespan of Swiss dairy cows: influencing factors, future scenarios and strategy development" mainly financed by the Swiss Federal Office for Agriculture (OFAG, contract number: 627001582, Bern, Switzerland) with further financial support from the Association of Swiss Cattle Breeders (ASR, Zollikofen, Switzerland), Bio Suisse (Basel, Switzerland), Fondation Sur-la-Croix (Basel, Switzerland), IP-Suisse (Zollikofen, Switzerland), Migros (Zürich, Switzerland), and Schweizer Milchproduzenten Swissmilk (SMP, Bern, Switzerland).

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