Received: 29 March 2024 | Accepted: 12 July 2024

DOI: 10.1111/rda.14690

REVIEW

Reproduction in Domestic Animals WILEY

Extended lactations in dairy cows and the effects on fertility and production

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Abstract

Extending lactation length reduces the frequency of critical calving events for the cow and herewith reduces the frequency of periods with increased risk for health problems. Moreover, breeding is postponed until a moment later in lactation, which is associated with better conception rates and less days open after start of the breeding period in most studies. Potential risks of an extended lactation are that milk yield of cows at the end of the lactation may be too low which may lead to cows being overconditioned at the end of the extended lactation. Therefore, extending lactation length might not fit every cow. Individual cow characteristics like parity, milk yield level, or body condition determine the response of the cow to an extended lactation. These individual cow characteristics can be used in customized management strategies to optimize lactation length for individual cows. Customized lactation length for individual cows could limit the impact at herd level of disadvantages concerning milk losses and overconditioning and maintain benefits for improved cow health and fertility, reduced number of surplus calves and increased work satisfaction for the farmer. In conclusion, extending lactation length has interesting perspectives for health and fertility of high-producing dairy cows, although questions remain concerning management approaches to support lactation persistency of cows with an extended lactation, and consequences for calf health and development. Moreover, ongoing studies aim to develop decision support tools to select individual cows for a specific lactation length.

KEYWORDS

calves, cattle, customized management, fertility, individual cow variation, milk production, practical implications

1 | INTRODUCTION: TRADITIONAL LACTATION LENGTH OF DAIRY COWS

In most dairy systems, cows are managed to calve every year. Evolutionary, a one-year calving interval (CInt) makes sense as it aligns with the seasonal calving in nature. In nature, calves are typically born in spring when nutrients are plentiful. Moreover, in nature, the cow normally produces milk to feed one calf, and therefore lactation can be expected to have a different curve, yield and length. This seasonal pattern is often replicated in pastoral dairy systems, where the system relies heavily on environmental nutrient availability (Dillon et al., 1995; Butler et al., 2010). However, in most dairy systems, the availability of silages and concentrate reduce the dependence on fresh feed from the environment facilitating calves to be born throughout the year. Moreover, milk production year-round may be beneficial and supported by higher milk prices in specific seasons. As a result, in most intensive or semi-pastoral dairy systems calves are born throughout the year. Nevertheless, farmers still aim for a short CInt of about one year. The reason behind this is that a yearly calving is associated with a yearly peak in milk production in the beginning of every new lactation (Dijkhuizen et al., 1985; Steeneveld & Hogeveen, 2012). In practice, however, calving intervals mostly exceed one year (Figure 1).

A consequence of a yearly CInt is that cows experience the transition from lactation to the dry period, and a few months later also the transition from the dry period to calving and the start of a new lactation each year. These transitions are not only characterized by significant changes in cow physiology but also changes in ration, housing and management. A successful adaptation during these transitions is crucial to reduce the incidence of health and fertility problems, as failure to adapt may lead to compromised health (Lancet, 2009), welfare (Zobel et al., 2015) and fertility (as reviewed by Pascottini et al., 2022) and potentially culling (Pinedo et al., 2014). In particular the start of a new lactation, when cows are recovering from calving and simultaneously start the new lactation, entails an elevated risk of metabolic disorders and diseases (Fleischer et al., 2001; Koeck et al., 2012; VÄXA, 2023a). Moreover, it is well known that these diseases and disorders in early lactation are strongly associated with altered ovarian cyclicity (Opsomer et al., 2000), delayed resumption of ovarian cyclicity (Vercouteren et al., 2015), and compromised reproductive performance (Pinedo et al., 2020), possibly related to altered feed intake behaviour and a lower feed intake of cows with delayed resumption of ovarian activity (de Bruijn et al., 2023).

Deliberately extending the lactation length increases the CInt and thereby reduces the frequency of transition periods for dairy cows (as reviewed by Bertilsson et al., 1997; Knight, 2005; Sehested et al., 2019; Van Knegsel et al., 2022) (Figure 2) and herewith has the potential to reduce the incidence of health and infertility problems at cow and herd level. Moreover, extending the lactation by extending the voluntary waiting period (VWP) post-calving may be a strategy to postpone artificial insemination (AI) for cows with compromised fertility in early lactation, to prevent issues with high milk production at dry-off, and to reduce the surplus of calves in the dairy sector. Extended lactations, however, could also have disadvantages. When the frequency of calving is reduced, cows have a lower frequency of

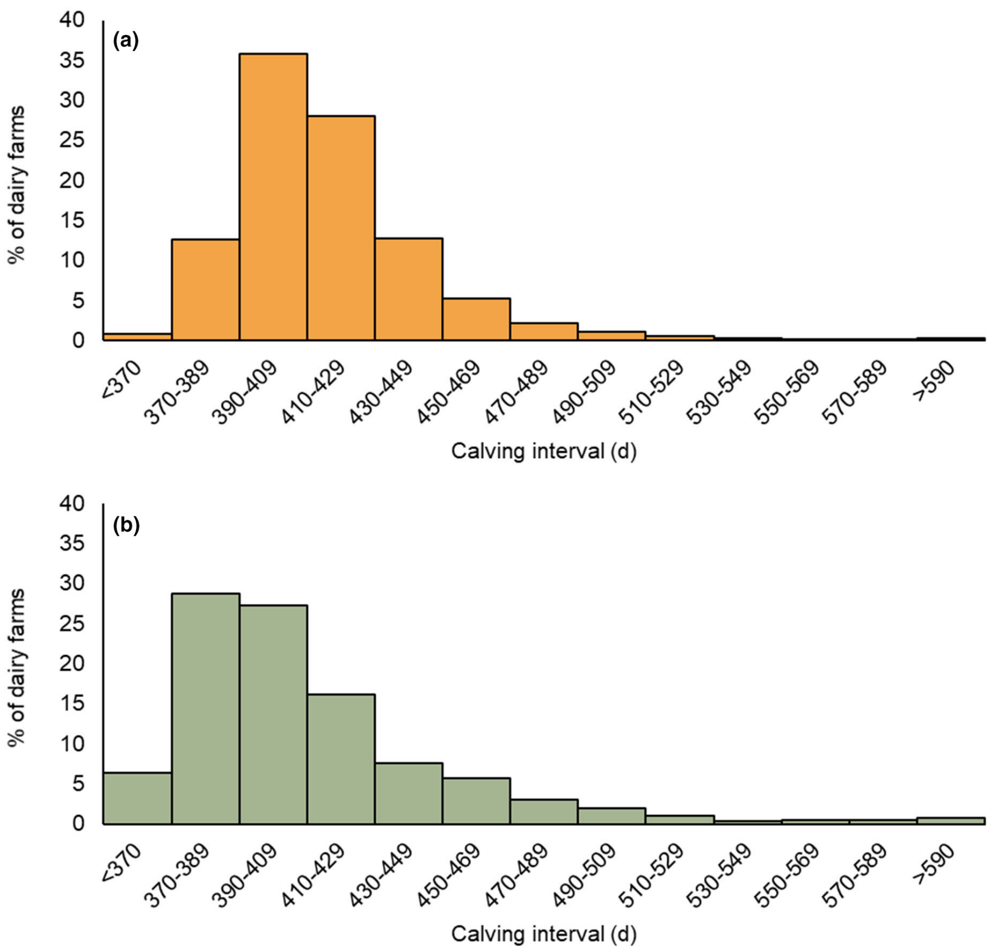

FIGURE 1 (a) Distribution of Dutch dairy herds (*N* = 11,405) by calving interval, based on data from 1 September 2022–31 August 2023 (CRV, 2024); (b) Distribution of Swedish dairy herds (*N* = 1771) by calving interval, based on data from 1 September 2019–31 August 2020 (VÄXA, 2023b).

FIGURE 2 Schematic representation of milk production over 3 years for a conventional lactation cycle with a short voluntary waiting period (VWP) and an extended lactation cycle with an extended VWP, assuming no effect of pregnancy on persistency of the lactation curve (Adopted from Knight, 2005).

peaks in milk yield, and spend a smaller proportion of time in early lactation, when milk yield usually is higher. For cows not able to sustain a persistent lactation, being dried off early, or for low-yielding cows, a lower average daily milk yield could reduce the farmer's income, and increase environmental impact (Kok et al., 2019; Lehmann et al., 2019). Moreover, milk production typically decreases after the lactation peak and, with an extended lactation, cows spend a greater proportion of time in the period between lactation peak and dry-off. Consequently, cows with a less persistent lactation curve or low yield may face an increased risk of overconditioning at the end of the extended lactation, potentially compromising metabolic status (Burgers et al., 2023) and health after the next calving moment. As a result, there is an increasing focus on customizing lactation length for individual cows to optimize the advantages of an extended lactation, while mitigating the potential disadvantages of extended lactations.

First, the focus of this review will be on the consequences of an extended VWP for fertility and health, as reported in experimental studies in which the lactation period of dairy cows was deliberately extended by extending the VWP. Second, consequences of an extended VWP for milk yield will be reviewed, including both historic studies which contributed to the advice for a one-year CInt and more recent experimental studies. Third, recent research on customized lactation length strategies based on individual cow characteristics will be reviewed. Recently, consequences of extended lactations on milk yield, fertility, calves, net herd returns and environmental impact of dairy systems were reviewed (Sehested et al., 2019; Van Knegsel et al., 2022). The current review will give an update on the state of knowledge, with also a specific focus on fertility outcomes, customized lactation length strategies and selection of individual cows for a specific lactation length.

2 | CONSEQUENCES OF AN EXTENDED LACTATION FOR FERTILITY

The relationship between CInt and fertility has been evaluated in retrospective studies earlier (Burgers et al., 2021b; Inchaisri et al., 2010). In retrospective studies, however, it is complicated to differentiate between extended CInt caused by voluntary extensions of the VWP and those originating from reduced fertility, such as decreased estrus expression, impaired estrus detection or failure to conceive. Therefore, interpretations of fertility outcomes from such studies should be approached cautiously. In this section, we specifically aim to review experimental studies that evaluated the consequences of an extended VWP on fertility.

2.1 | Experimental studies

In three out of six studies, an extended voluntary waiting period (VWP) led to a greater conception rate after first AI (CR1AI; ICAR recording guidelines, 2022) (Edvardsson Rasmussen et al., 2023a; Ma et al., 2022; Niozas et al., 2019b) (Figure 3a). However, one study reported no difference between VWP groups (Ratnayake et al., 1998). Schindler et al. (1991) found a greater CR1AI for multiparous cows while no difference for primiparous cows with extended VWP. In contrast Stangaferro et al. (2018) reported a greater CR1AI in primiparous cows while no difference in multiparous cows. Furthermore, Ma et al. (2022) reported an increase in CR1AI when the VWP was extended from 50 to 200 days, but not when the VWP was extended from 50 to 125 days.

Days open after the end of the VWP was fewer for cows with an extended VWP in three (Edvardsson Rasmussen et al., 2023a; Ma et al., 2022; Niozas et al., 2019b) out of eight studies (Figure 3b). One study reported a reduction in days open after end of the VWP for multiparous cows, but not for primiparous cows (Arbel et al., 2001). Three studies reported no effect of VWP on days open after end of the VWP (Schindler et al., 1991; Van Amburgh et al., 1997; Stangaferro et al., 2018). In contrast to later studies, Schneider et al. (1981) reported a higher number of days open for cows with a VWP of 80 days, compared with a VWP of 50 days; however, the increase in VWP was relatively small (from 50 to 80 d), similar to the study by Stangaferro et al. (2018) (60–88 d).

The average number of inseminations needed per conception (NINS) is a commonly used fertility metric, indicating the efficiency and cost-effectiveness of AI (Figure 3c). One early study by Schneider et al. (1981) reported a higher NINS, in cows with extended VWP, consistent with their results with higher number of days open after VWP. However, two later studies found no effect of VWP length on NINS (Van Amburgh et al., 1997; Ratnayake et al., 1998), while three recent studies observed a lower NINS in cows with extended VWP

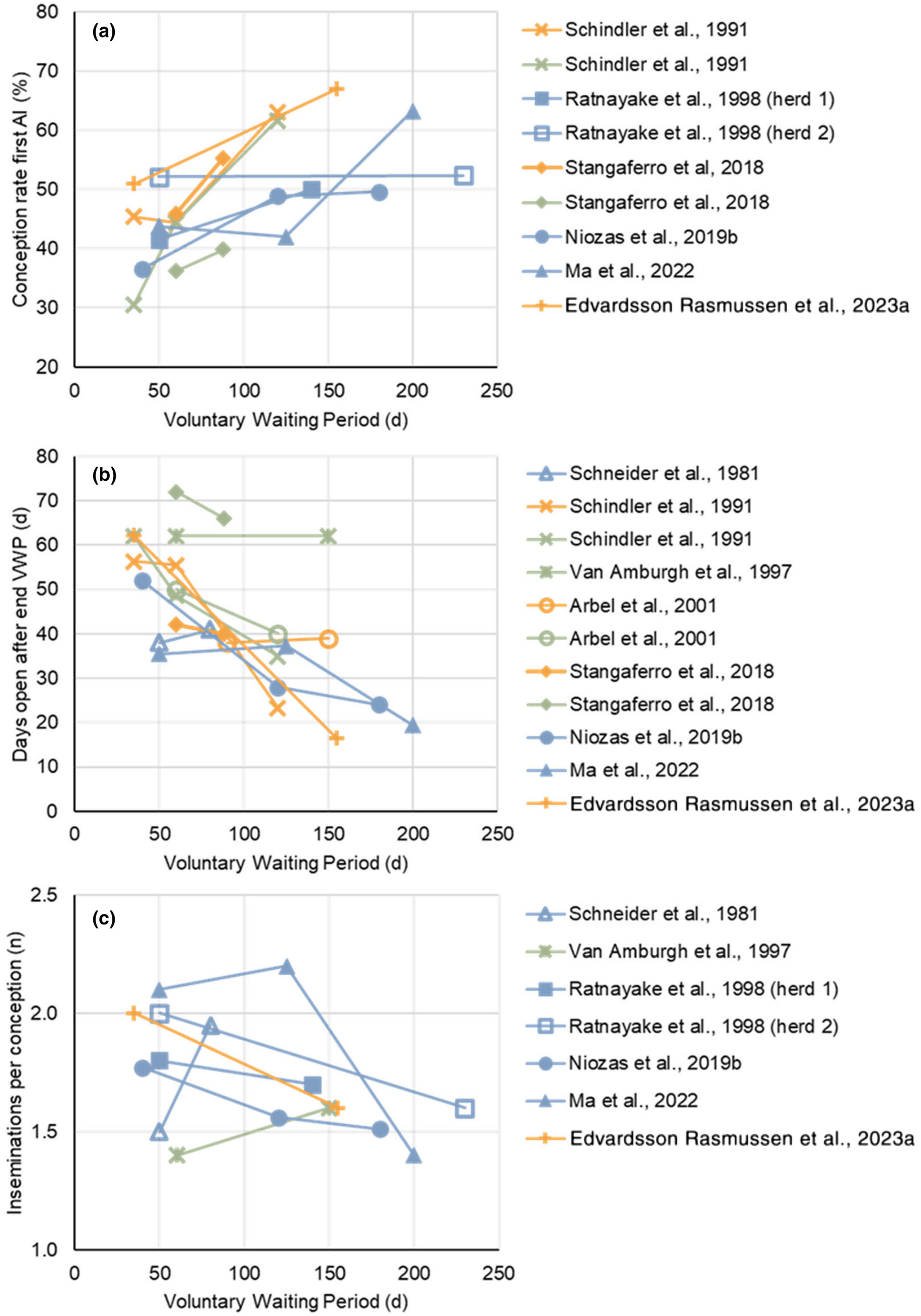

FIGURE 3 (a) Conception rate first artificial insemination, (b) days open, and (c) number of inseminations per conception after the end of the voluntary waiting period (VWP) for cows that were pregnant per VWP in each experiment, with one data point per treatment group per study. Orange = primiparous cows, green = multiparous cows; blue = both primiparous and multiparous cows. Values presented in the figure are available in Table S1 (Figure is adopted from Van Knegsel et al., 2022).

(Edvardsson Rasmussen et al., 2023a; Ma et al., 2022; Niozas et al., 2019b).

Extending the VWP also increased the proportion of cows seen in estrus within 46 days after end of the VWP, from 70.4% in cows with 40 days VWP to 88.9% and 90.8% in cows with 120 and 180 days VWP (Niozas et al., 2019b). Also, extending the VWP increased the proportion of cows with high estrus intensity (score 4–5) (Edvardsson Rasmussen et al., 2023a) as reported by the farmer at the time of first insemination on a scale from 0 to 5 with 0 being no signs of estrus and 5 being strong signs of estrus, from 42 to 60% in cows with 35 and 155 d VWP. Ratnayake et al. (1998) reported that the proportion of cows expressing normal heat signs at each cycle number after calving increased until the 4th cycle after calving and thereafter remained constant, which is line with increased estrus expression in cows with an extended VWP in the other studies.

Few studies have examined the consequences of an extended VWP on pregnancy loss (Edvardsson Rasmussen et al., 2023a; Niozas et al., 2019b; Stangaferro et al., 2018). Of these, two studies reported a higher, though not significantly, proportion of cows with pregnancy loss with an extended VWP (Edvardsson Rasmussen et al., 2023a; Stangaferro et al., 2018), while one study reported a smaller, though not significantly, proportion of pregnancy loss (Niozas et al., 2019b). The number of cases, however, in all three studies was low, ranging from 3% to 8% and these studies were probably underpowered to draw any conclusions.

2.2 | Possible reasons for fertility consequences of an extended lactation

Several reasons potentially explain the effect of an extended VWP on fertility. First, lower milk yield at the end of the VWP may contribute to improved fertility in cows with an extended VWP. Multiparous cows with a VWP of 200 or 125 d had a lower milk yield at the end of the VWP compared with cows with a VWP of 50 d (27.5 vs. 32.0 vs. 37.4 kg/d; $p < 0.01$), but not for primiparous cows with different VWP (Ma et al., 2022). In that study, the correlation between milk yield around the end of the VWP and days open after end of the VWP was weak ($r = 0.31$; $p < 0.01$; Ma et al., 2022), indicating that additional factors are involved in the relation between an extended VWP and fertility. Studies not specifically focused on extended lactations have confirmed a negative association between milk yield and fertility. For example, in a meta-analysis, CR1AI decreased by 2.0% with each additional 1 kg of milk yield at peak, and by 2.2% with each additional 1 kg of milk yield at service (Bedere et al., 2018). Additionally, estrus length, intensity and estradiol concentrations during estrus have been negatively related to milk production level (Lopez et al., 2004). Furthermore, embryo loss occurred more frequently in high-yielding cows (Grimard et al., 2006), with an odds ratio of 1.74 in cows with >39 kg peak yield. However, other studies could not confirm a correlation between embryo loss and milk yield (Bruinjé et al., 2023; Chebel et al., 2004). Variations among studies concerning the relationship between embryo loss and milk yield level may potentially be due to differences between studies in 1. herd fertility status, as Grimard et al. (2006) specifically studied low fertility herds; 2. differences in occurrence of postpartum health disorders, as Chebel et al. (2004) found mastitis to affect pregnancy loss, and Bruinjé et al. (2023) found that postpartum health disorders may affect pregnancy recognition signalling and early pregnancy placental function.

Second, it has been suggested that a more positive energy balance (as discussed by Bertilsson et al., 1997; Sehested et al., 2019) and altered metabolic status (Burgers et al., 2023) at the end of VWP contribute to reduced days open after an extended compared with a conventional VWP. Burgers et al. (2023) found that multiparous cows with a 200 d VWP had a higher plasma insulin and IGF-1 concentration at the end of the VWP compared with cows with a 125 or 50 d VWP. However, at the time of the insemination leading to pregnancy, plasma insulin concentration did not differ among the VWP groups (Burgers et al., 2023). This could indicate that the insulin concentration at the time of conception may be important for insemination success. The positive association between energy balance, metabolic status and reproductive performance has been extensively reviewed (e.g. Pascottini et al., 2022; Walsh et al., 2011) and the current results from experimental studies where the insemination moment is deliberately extended to a period with a better energy balance and metabolic status seem to support these earlier studies.

Third, improved conception rates in cows with extended compared with shorter VWP could be linked to an increased number of, as well as more regular, ovarian cycles after the extended VWP. Conception rate was improved if cows had more luteal phases, with at least one of normal length, before the first insemination (Bruinjé et al., 2017). More recently, extending VWP from 50 to 125 d or 200 d resulted in a greater percentage of normal cycles (of 18–24 d) around the end of the VWP, with a lower percentage of prolonged cycles (>24 d) for cows with a VWP of 200 d (Ma et al., 2022).

Fourth, extending the VWP provides cows more time to recover after calving from potential complications and early lactation disease events. Disease incidence is highest during the weeks around calving, especially in multiparous cows (Ingvartsen et al., 2003; VÄXA, 2023a). Mastitis and transition diseases, like, retained placenta, endometritis, metritis and ketosis, negatively impact fertility (Bogado Pascottini et al., 2020; Bruinjé et al., 2023, 2024; Ribeiro et al., 2016). Early lactation disease events were associated with lower pregnancy rates for inseminations performed before, but not after, 150 DIM in a retrospective study (Carvalho et al., 2019). Thus, extending the VWP allows cows more time to recover from diseases in early lactation, which may be another explanation to the improved fertility for cows with extended VWP.

While factors like milk yield, energy balance, metabolic status, ovarian cyclicity, and post-calving recovery may all contribute to improved fertility when the VWP is extended, their interaction is complex and not yet fully understood.

3 | CONSEQUENCES OF AN EXTENDED LACTATION FOR DISEASE, CULLING AND PRODUCTIVE LIFE

3.1 | Disease

Cows with a longer lactation spend more time at risk for disease during each lactation, but proportionally less time in the critical time window around calving and start of a new lactation. Six out of eight studies reported fewer disease events per cow per year when the VWP was extended (Ratnayake et al., 1998; Edvardsson, 2012; Niozas et al., 2019a, 2019b) (Figure 4). Two out of eight studies reported a higher number of diseases events per cow per year when the VWP was extended (Edvardsson Rasmussen et al., 2023a; Van Amburgh et al., 1997), and one study found similar results in all three VWP groups (Van Knegsel et al., 2022).

There are considerable differences among studies which diagnoses were reported and the frequency of reported diseases. Further, most studies have reported the number of cases per lactation, which means that cows with extended lactations spend a longer time at risk, compared with cows with a shorter lactation length. Therefore, disease cases in each study were recalculated to be expressed as the number of cases per 100 cow-years at risk, calculated as the number of reported disease cases in each VWP treatment, divided by the number of cows in each treatment multiplied by the sum of time (in years) that all cows in each VWP treatment spent in the study, multiplied by 100. Thus, these results should not be used to compare the level of disease incidence among studies, as it may rather reflect the different methods used to define and register disease cases. Within each study, however, the results are comparable among the VWP treatments. Furthermore, besides differences in disease diagnosis protocol, number of cows in the studies and study period were limited. Larger and more long-term studies are necessary to clarify the consequences of an extended VWP on disease incidence.

3.2 | Culling and productive life

Three studies reported a numerical, but not statistically, higher culling incidence (Burgers et al., 2022; Niozas et al., 2019a; Van Amburgh et al., 1997), while one study reported a numerically, but not statistically tested, lower culling incidence (Österman & Bertilsson, 2003) for cows with an extended VWP compared with a shorter VWP. Stangaferro et al. (2018) reported a slightly lower number, but not significantly, of primiparous cows culled in the extended VWP treatment, however, the opposite results for multiparous cows. Arbel et al. (2001) reported a numerically higher, but not significantly, culling incidence for primiparous cows and a lower for multiparous cows with an extended VWP compared with a shorter VWP.

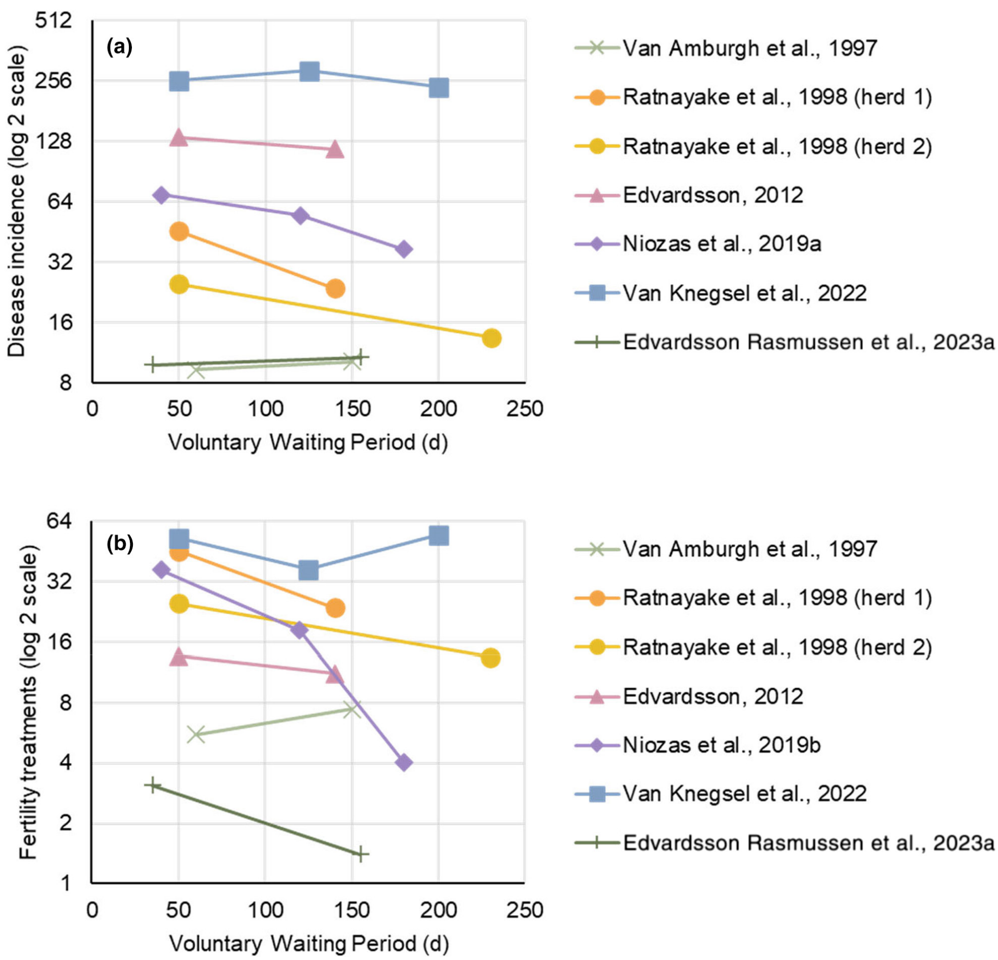

FIGURE 4 (a) Total number of reported disease incidents and (b) fertility treatments per 100 cow-years at risk (calculated as the total number of disease events/fertility treatments per VWP group divided by the number of cows multiplied by the number of years at risk per VWP group, multiplied by 100) per voluntary waiting period (VWP) in each experiment, with one datapoint per treatment group. Values presented in the figure are available in Table S2.

Most studies reported the culling incidence only for the included cows following the research protocol, i.e. 'per protocol', as opposed to reporting culling incidence for all cows randomized to each treatment regardless if they received the planned treatment or not, i.e. 'intention to treat' (Mansournia et al., 2017). There might be a bias risk if cows randomized to a treatment did not receive the intended treatment due to a reason that may be connected to the treatment. However, when culling incidence was reported both "per-protocol" and as "intention to treat" (Edvardsson Rasmussen et al., 2023a) culling incidence reported only for cows receiving 'per protocol' treatment was numerically higher, but not significantly, for cows with extended VWP and lower when reported for all cows, i.e. "intention to treat". One reason might be that the risk of culling is higher for cows that did not conceive (Gröhn et al., 1998), and for cows with extended VWP as they spend longer time "at risk" of being culled before first AI.

In line with disease records, also recording of culling and reasons for culling varied among studies. In retrospective studies, Owusu-Sekyere et al. (2023) concluded that CInt was associated with higher herd longevity, and Remmik et al. (2020) and Römer et al. (2020) found similar results, linking longer first lactation CInt with extended productive life. To our knowledge, long-term randomized studies examining the effects of voluntary waiting periods (VWP) on longevity and productive life are currently lacking.

4 | CONSEQUENCES OF AN EXTENDED LACTATION FOR MILK YIELD

In earlier literature, consequences of lactation length for milk yield were evaluated using a retrospective approach or later also a modelling approach. More recently, experimental studies were executed where cows were blocked for, e.g. parity or milk yield level and within blocks randomly assigned to treatments. Both types of studies are reviewed in this section.

4.1 | Retrospective and modelling studies

The optimal CInt to maximize milk yield was already addressed 100 years ago. These early retrospective studies of optimal CInt length reported that the CInt should not be shorter than 12 months (Hammond & Sanders, 1923; Matson, 1929; Sanders, 1927). In another study, an extension of the CInt to 18 months did not affect average yield (Gaines & Palfrey, 1931). Several authors further reported that yield in the current lactation was correlated to an increased length of the previous CInt (Gaines & Palfrey, 1931; Johansson & Hansson, 1940; Matson, 1929). Results of these early studies already indicated that the optimal length of the CInt might depend on parity of the cow, with a longer CInt of around 13 until 14 months suggested for primiparous cows, and a shorter interval for multiparous cows (Johansson & Hansson, 1940; Louca & Legates, 1968).

Until today, worldwide, most dairy farmers are advised to aim for a short CInt or even a CInt of 365 days, which typically means that the lactation period extends to around 305 days. This practice has evolved historically, as depicted above, and was later supported by economic models (Dijkhuizen et al., 1985; Strandberg & Oltenacu, 1989). Estimates for economic impact of extended lactations range from 0.00 to 2.80 € per cow per day (Groenendaal et al., 2004; Inchaisri et al., 2011; Steeneveld & Hogeveen, 2012). At farm level, the costs of prolonged lactation can accumulate significantly according to these models (Steeneveld & Hogeveen, 2012). However, a limitation regarding these analyses for optimizing lactation length and AI timing is, firstly, that they are based on cows that were inseminated relatively early and where AI timing was not deliberately postponed. Secondly, it was often unknown why the lactation period was extended. It is possible that health or fertility problems in early lactation contributed to delayed pregnancy resulting in the long lactation. Moreover, in these cows, illness or disorders in early lactation could not only be related to the prolonged lactation but could also result in productivity loss (Hostens et al., 2012). Thirdly, these retrospective analyses do not, or only minimally, take into account animal health and the actual number of calves needed to replace the herd. A recent study shows that it is not necessary to retain all heifer calves for replacement on an average Dutch dairy farm (Mohd Nor et al., 2015). In this study, the optimal number of calves needed for replacement depended on farm and herd characteristics, including age at first calving, culling rate of the dairy cows in the herd and costs for empty slots in the herd.

4.2 | Experimental studies

4.2.1 | Milk yield per day in the calving interval

The overall impact of extended lactations on milk production is best assessed by milk yield per day in the calving interval (MY/CInt) (Österman & Bertilsson, 2003; Lehmann et al., 2016). The MY/CInt takes into account not only all lactating and dry days but also the complete late lactation period. This period is typically extended for cows with an extended VWP, during which milk production is generally at its lowest.

For multiparous cows, a longer VWP resulted in a lower MY/CInt in three out of six studies (Arbel et al., 2001; Burgers et al., 2021a; Österman & Bertilsson, 2003) (Figure 5) with no effect in two out of six studies (Rehn et al., 2000; Stangaferro et al., 2018) and a higher yield in one study (Van Amburgh et al., 1997), although in the last study, different VWP in combination with bST treatment after peak yield was evaluated. Notably, the two studies reporting no effect of VWP on MY/CInt for multiparous cows, were the study with the shortest VWP and the shortest extension of the VWP (Stangaferro et al., 2018) and the study with relatively low milk yield level (Rehn et al., 2000). For primiparous cows, a longer VWP resulted in a greater MY/CInt in three out of six studies (Arbel et al., 2001; Burgers et al., 2021a; Österman & Bertilsson, 2003), with no effect in three other studies

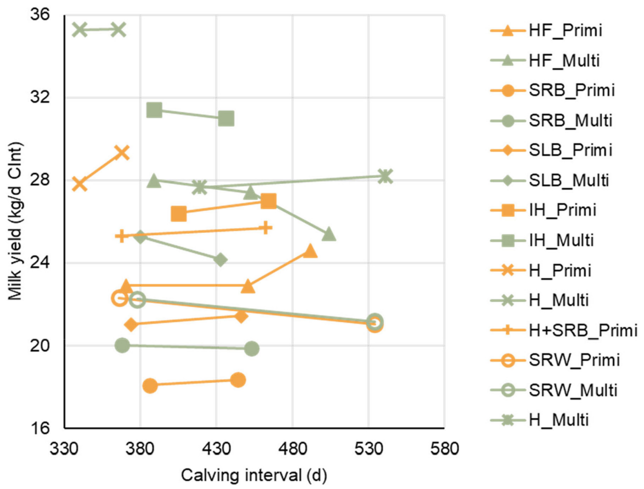

FIGURE 5 Milk yield per day of calving interval (CInt) for primiparous and multiparous cows in experimental studies with deliberate extension of VWP; one data point per parity per treatment group. HF = Holstein Friesian cows, study of Burgers et al. (2021a); SRB = Swedish Red and White, SLB = Swedish Holstein, study of Rehn et al. (2000); IH = Israeli Holstein, study of Arbel et al. (2001); H = Holstein, study of Stangaferro et al.(2018) (note: Based on cows pregnant at first AI only); H + SRB = Holstein and Swedish Red and White, study of Edvardsson Rasmussen et al. (2023b); SRW = Swedish Red and White, study of Österman and Bertilsson (2003); H_Multi = Holstein, study of Van Amburgh et al. (1997). Values presented in the figure are available in Table S3 (Figure is Adapted from Van Knegsel et al., 2022).

(Rehn et al., 2000; Stangaferro et al., 2018; Edvardsson Rasmussen et al., 2023b). Furthermore, Österman & Bertilsson (2003) extended the VWP across multiple lactations, and observed similar energy-corrected milk yields per day of CInt for cows with three 12-month lactations compared with cows with two 18-month lactations. Milk fat, protein and lactose content in the first 44 weeks of lactation were not affected by a VWP of 50, 125 or 200 d (Burgers et al., 2021a), yet were shown to increase in the extended lactation of 18 months, compared with 12 months (Österman & Bertilsson, 2003).

The differences in the impact of VWP on MY/CInt among studies may be explained by variations in VWP lengths evaluated in the different studies, dry period length, absolute milk yield level and shape of the lactation curve of the cows in these studies. Some (Edvardsson Rasmussen et al., 2023b; Niozas et al., 2019a), but not all (Burgers et al., 2021a) reported an increase in dry period length when the VWP was deliberately extended. The dry period in itself has zero contribution to lactation yield. Depending on the actual lactation length and potential consequences of extension of the VWP for dry period length the ratio of dry days to lactating days might shift, impacting the effect of VWP on MY/CInt.

4.2.2 | Lactation persistency

Extending the VWP resulted in more persistent lactation curves (Figure 6), independent of whether persistency was defined as the rate of decline in the Wilmink lactation curve (Niozas et al., 2019a), decline in milk yield from 100 days in milk (DIM) until dry-off (Burgers et al., 2021a) or decline in milk yield from 100 until 305 DIM (Schneider et al., 1981). The positive impact of an extended VWP on persistency may at least partially be explained by the delayed negative effect of pregnancy on the lactation curve (Rehn et al., 2000; Strandberg & Lundberg, 1991).

5 | CUSTOMIZING LACTATION LENGTH

Although extending the VWP can benefit cow health and fertility, there are potential drawbacks associated with an extended VWP, including decreased milk yield and increased overconditioning of cows towards the end of lactation. Furthermore, the response of cows to an extended VWP varied among cows partly depended on individual cow characteristics. Dairy farmers recognized that not all cows are suitable for an extended VWP (Burgers et al., 2021b). In this previous study monitoring commercial dairy farms which deliberately extend the VWP to extend the lactation, the approach to extend the lactation varied among farmers. While some farmers (3/13) implemented a fixed VWP for their entire herd, the majority (10/13) applied a customized approach based on individual cow characteristics. Individual cow characteristics used by the farmers were parity, milk yield level, BCS or a combination of characteristics. Consequently, cows with a shorter CInt at these farms had a lower peak milk yield and 305-d milk yield, whereas cows with a longer CInt had a greater 305-d milk yield and a more persistent lactation curve. So farmers seem to select cows with a high milk yield for an extended lactation (Burgers et al., 2021b; Lehmann et al., 2017) to ensure milk yield towards the end of the lactation, mitigate the risk for overconditioning and potentially benefit from reduced milk yield at dry-off and fewer critical calving events particularly for high-producing cows.

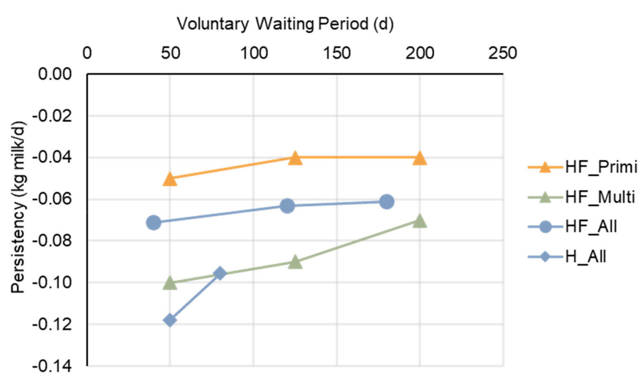

FIGURE 6 Persistency of the lactation curve in experimental studies with deliberate extension of VWP; one data point per treatment group. HF_Primi, HF_Multi = Holstein Friesian cows, study of Burgers et al. (2021a); HF_All = Holstein-Friesian cows, study of Niozas et al. (2019a); H_All = Holstein cows in the study of Schneider et al. (1981). Values presented in the figure are available in Table S4.

6 | TOWARDS THE DEVELOPMENT OF DECISION SUPPORT TOOLS

Recently, research groups (Sanftleben et al., 2022) and farm-advisors developed and started working with decision support tools to aid the farmer's choice for the moment of insemination post calving. These tools included milk yield information available in early lactation, and parity of the cows for their advice. Besides the development of these decision support tools, several research groups focused on forecasting (Innes et al., 2024) or predicting (Burgers et al., 2023; Chen et al., 2023) cow performance or suitability of cows for an extended lactation. Cow performance was in these studies defined as milk yield in last 6 weeks of the lactation (Burgers et al., 2023), milk yield at 305 DIM (Innes et al., 2024), lactation persistency (Chen et al., 2023) or milk yield in the complete lactation (Burgers et al., 2023). Although modelling approach and origin of data used in these studies were quite variable, all these studies used milk yield characteristics and parity of the cow to indicate suitability of cows for an extended lactation.

Besides consequences for milk yield, also consequences for cow health and body condition can be considered to be relevant for the decision to extend the lactation. Body condition score in the last 12 weeks of the lactation could be well predicted by body weight, body condition score and milk characteristics in early lactation using experimental data (Burgers et al., 2023).

Studies are ongoing to further fine tune models to predict the optimal insemination moment for individual cows. Besides milk characteristics or body condition variables, it can be hypothesized that also historic information of cows (Nordlund, 2006), disease records (Hostens et al., 2012) or milk fatty acid profiles (Churakov et al., 2021; Gross et al., 2011) have added value to predict the milk performance or risk for overconditioning of individual cows. Moreover, the benefit of reducing the risk for calving-related diseases might be depended on individual cow characteristics like parity (VÄXA, 2023a) or milk yield level, which could be considered to be included in the decision to extend the lactation or not for an individual cow.

7 | PRACTICAL IMPLICATIONS AND REMAINING QUESTIONS

Besides limited data on consequences for disease and productive lifespan, and ongoing research on the development of decision support tools, more aspects need to be considered when discussing the practical implications of an extended lactation.

Maintaining milk yield and lactation persistency and prevention of overconditioning in cows with an extended lactation has been evaluated in a limited number of studies. Management strategies like increasing milking frequency (Österman et al., 2005; Sorensen et al., 2008), administering bST (Van Amburgh et al., 1997; Stangaferro et al., 2018) or adjusting dietary energy content (Gaillard et al., 2016; Grainger et al., 2009; Sorensen et al., 2008) to maintain milk yield and manage overconditioning in an extended lactation were evaluated. Additionally, breeding approaches or other feeding strategies such as increasing dietary protein (Law et al., 2009) or increasing lipogenic nutrient availability (Van Hoeij et al., 2017) may also improve lactation persistency or regulate body fat accumulation in cows at the end of an extended lactation.

Deliberately extending the lactation length can be a strategy for farmers to reduce the number of surplus calves (Van Dooren, 2019). These surplus calves are of growing concern not only among farmers but also in science, politics and society, due to the welfare implications of transport and the ongoing debate concerning management of these young calves (Bolton & von Keyserlingk, 2021).

Besides the impact on management of calves, deliberately extending the lactation length can be hypothesized to affect health and development of dairy calves. Extending the VWP implies that cows are inseminated later in lactation, where milk production is lower and body condition and metabolic status are improved, compared with insemination earlier in lactation (Burgers et al., 2023). Earlier, milk production level of the cow during the breeding period was negatively related with milk production and survival of the offspring (Berry et al., 2008). Also, nutrition and health of the cow during gestation has been related to antral follicle count in their offspring (Evans et al., 2012). Studies are ongoing (Wang et al., 2023) evaluating the consequences of metabolic status of the cow during the conception period on health and development of her calf during early and later life.

For implementation in dairy practice, consequences of an extended lactation at herd level and financial returns are crucial. Consequences at herd level could include effects on availability of youngstock for replacement when fewer calves are born. Also lactation stage or age distribution within the herd might shift when the lactation is extended. Although primiparous cows are well suited for an extended lactation due to their persistent lactation curve and low risk for overconditioning (Burgers et al., 2023), it will delay the start of their second lactation when normally milk yield is higher. Besides herd dynamics, economic evaluations of an extended or customized lactation should include also disease, fertility, labour and veterinary costs. Additionally, extending lactation length can impact labour hours spent on tasks such as calving, calf care, milking and care for diseased animals, but also the quality of work and job satisfaction.

8 | CONCLUSION

Extending the lactation length by extending the VWP can improve health and fertility of high-producing dairy cows. With extending the lactation length the frequency of critical calving events for the cow reduces, herewith reducing the frequency of periods with increased risk for health problems. Additionally, breeding is postponed until a moment later in lactation, which was associated with better conception rates and fewer days after end of the VWP until conception. Potential risks are that milk yield of cows at the end of lactation is too low to extend the lactation period possibly associated with overconditioning at the end of the lactation. Customized lactation length could limit the impact at herd level of disadvantages concerning milk losses and overconditioning and maintain benefits for improved cow health and fertility, reduced number of surplus calves and increased work pleasure for the farmer.

AUTHOR CONTRIBUTIONS

AVK and AER have discussed the content of the paper and wrote the first draft of the paper. EAB made figures 1, 2, 3, 5 and 6. AER made figure 4. AER, EAB and AVK have read and corrected the paper.

ACKNOWLEDGEMENTS

The authors would like to thank Dr Ann Nyman and VäxaSverige for sharing the data for Figure 1b.

CONFLICT OF INTEREST STATEMENT

None of the authors has any conflict of interest to declare.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created.

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How to cite this article: van Knegsel, A. T. M., Burgers, E. E. A., & Edvardsson Rasmussen, A. (2024). Extended lactations in dairy cows and the effects on fertility and production. *Reproduction in Domestic Animals*, *59(Suppl. 2)*, e14690. https://doi.org/10.1111/rda.14690