Extended calving interval in sick first calvers

Effects on milk yield and reproduction

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Abstract

Milk production has steadily increased during the recent decades, both in yield and milk solids. However, a higher milk production can be associated with reproductive problems resulting in challenges with fertility. A traditional 12 month calving interval (CI) with a voluntary waiting period (VWP) of 50-60 days is because of this harder to achieve, especially if the cow is sick postpartum. The aim of this thesis was therefore to evaluate if cows, sick during the first 30 days postpartum, that are given a longer VWP, and also a longer CI, will need fewer inseminations before getting pregnant. It was also hypothesized that those cows would have a higher total milk yield. A literature review and statistical analysis of data was carried out, the data was available from previous trials. The findings showed no difference between an extended (EXT) VWP and a conventional (CONV) VWP when it comes to dry days. The total lactation milk yield and 305 days milk yield was higher for cows on an EXT VWP plan. Milk yield per day of CI was higher for cows on an EXT plan but did not differ significantly. Neither did number of inseminations (NINS), cows on an EXT plan required 1.7 inseminations and cows on a CONV plan needed 2.1. First service conception rate (FSCR) was higher for cows on an EXT plan at 69% compared to cows on a CONV plan were 61% of the cows required more than one insemination to get pregnant. These results indicate that primiparous cows that express signs of sickness during the first 30 days postpartum can benefit from receiving an EXT plan, to what extent is likely to vary greatly depending on herd and their management.

Keywords: voluntary waiting period, dairy cattle, primiparous, first lactation

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Abbreviations

CI	Calving interval
CONV	Conventional
DIM	Days in milk
DPL	Dry period length
ECM	Energy corrected milk
EXT	Extended
FSCR	First service conception rate
HOL	Holstein
NEB	Negative energy balance
NINS	Number of inseminations
RDC	Red dairy cattle (Swedish Red, Danish Red, Swedish Ayrshire)
SCC	Somatic cell count
SNDRS	Swedish national dairy herd recording scheme
VWP	Voluntary waiting period

1. Introduction

In recent decades milk production has steadily increased, both in total milk yield and milk solids. Today, the average Swedish dairy cow has a production of 10 545 kilograms (kg) of energy corrected milk (ECM) (Växa Sverige 2024). However, an increased production can be associated with reproductive problems, as the production increases, challenges with fertility also increase (Dobson et al. 2008).

The strive for a 12 month calving interval (CI) is based on economical calculations looking at milk production, feeding and housing. These calculations, however, does not take costs due to diseases and treatments into consideration (Ratnayake et al. 1998). The modern dairy cow does not only have a high production capacity, they also have the capacity to maintain it during extended periods of time (Knight 2005). When managing cows to calf once a year (Van Knegsel et al. 2024), the typical time for dry off is around 10 months after calving (Rodríguez-Godina et al. 2021). So, in common practice, as the milk production is increasing, drying off at high production levels has become more common, likely effecting udder health and cow comfort negatively (Österman et al. 2005).

To be able to achieve a 12 month CI it is important that reproductive functions are resumed quickly after calving (Ratnayake et al. 1998). With a CI of 12 months, the cow is subjected to a transition period once every year. The transition period consists of drying off, calving, onset of a new lactation and therefore also changes in management (Van Knegsel et al. 2022). To maximise the chances of a successful pregnancy result it is important that the transition cow management minimises the risks of peripartum diseases (Roche et al. 2018). A successful transition cow management will maximise the likelihood of a successful pregnancy (Roche et al. 2018) and lead to a more beneficial reproductive performance (Ma et al. 2022).

The voluntary waiting period (VWP), defined as the interval between calving and when the cow receives her first insemination (Edvardsson Rasmussen et al. 2023b), is typically 50-60 days when aiming for a CI of 12 months (Ratnayake et al. 1998). But it is not unusual that the CI exceeds 12 months (Van Knegsel et al. 2024), according to Växa Sverige (2024) the average CI in Sweden is 13 months and that could be due to it being necessary with several inseminations before the cow gets pregnant (Van Knegsel et al 2024). By postponing the first insemination the cow gets more time to recover from calving, something that can be expected to benefit the cow's reproductive performance (Ma et al. 2022). Disease result in an inflammatory and stress response, affecting reproductive performance

negatively (Dobson et al. 2003). Cows affected by sickness during their transition period will because of this, most likely, need more time to recover before they receive their first insemination.

Heifers should be around 23-25 months at first calving (Steele 2020), but age at first calving often vary between farms, for example due to different management strategies. Heifers are still growing at the time of the first calving, resulting in the peak milk yield not being as pronounced as for multiparous cows (Gaillard et al. 2016). The lactation curve of heifers is therefore generally of a flatter shape, indicating that they have a higher persistency compared to multiparous cows (Österman & Bertilsson 2003).

Aiming for a 12 month CI comes with its challenges, due to several factors such as fertility issues and high production during dry off. An extended CI could be a management strategy that offers solutions to these challenges.

1.1 Aim and hypotheses

The overall aim of this thesis is to evaluate how primiparous cows reported as sick during the first 30 days after calving are affected by an extended VWP. The focus will be on what effects an EXT CI have on milk production and fertility, investigating if the approach of a longer CI could be more efficient. This is done by analysing literature and doing a statistical analysis of experimental data already collected were sick primiparous cows on a CONV and an EXT CI are compared to one another. With the literature and data as a base, the following hypotheses were evaluated:

- The sick cows that are given a longer VWP, and therefore also a longer CI, will require fewer inseminations to get pregnant.
- The sick cows that are given a longer CI will have a total lactation milk yield that is higher and won't require more dry days.

2. Materials and methods

2.1 Literature review

The main databases used when searching for scientific publications where PubMed and ScienceDirect, chosen due to their broad coverage of veterinary and agricultural sciences. Google Scholar was additionally used in cases where specific publications in full text couldn't be found on the databases earlier mentioned.

Search terms where used in different combinations, incorporating AND and OR to capture a wide range of relevant publications. The search included terms such as:

- "Calving interval OR voluntary waiting period AND dairy cattle"
- "Voluntary waiting period AND fertility AND dairy cattle"
- "Calving interval AND reproductive efficiency AND dairy cattle"
- "Voluntary waiting period AND reproductive efficiency AND dairy cattle"
- "Transition period diseases AND dairy cattle".

As a complement to the search, references from already cited publications were used.

2.2 Statistical analysis

Experimental data used in this thesis was available from two earlier studies (Edvardsson Rasmussen et al. 2023a; b, 2024) that had the aim to study extended CI. To collect the experimental data, field trials were carried out on commercial dairy herds in southern Sweden, with ethical approval from Uppsala Ethics Committee for Animal Research, Uppsala, Sweden under permit number 5.8.18-10126/2018. The first study was a randomized trial with a total of two treatments, either conventional (CONV; 35 to 85 days) or extended (EXT; 155 to 206 days) VWP. Results from the first study were used when designing the second customized study where the cows were allocated for an EXT VWP based on their expected suitability.

A total of 80 cows were selected to be a part of the analysis, 29 from the randomized study and 51 from the customized study. There was only one criterion for being included; the cow must have been registered as sick during the first month after calving. One cow from each study had to be removed from the analysis. One of the cows due to being culled 3 days in milk (DIM) and the second one due to still being in lactation when data collection was finished. Due to this, there were 78 cows that were a part of the final analysis, of which 22 were

culled sometime between 56 and 715 DIM. All cows registered as sick during their first 30 days postpartum was included in this thesis analysis, regardless of their compliance with their assigned plan. The initial organization of data was done in Microsoft Excel 2016. Statistical analysis was performed using SAS (SAS Institute, version 9.4).

The following variables were analysed:

- Total lactation yield (kg ECM)
- CI (days)
- Milk yield per day of CI (kg ECM)
- Number of inseminations (NINS)
- 305-days milk yield (kg ECM)
- First service conception rate (FSCR)
- Dry period length (DPL; days)

In Table 1 disease diagnosis and the number of cows diagnosed are presented. All of the cows included were sick during the first month after calving, some of the cows got several diagnoses during this time. 92 diagnoses were registered on 77 different cows, one cow didn't have a diagnosis. *Other diagnosis* was used if the diagnosis was unsure or didn't match the diagnoses that were specified, for example an infection or a trauma of some sort. Three of the included cows got their diagnosis 1 to 7 days before calving but were included anyway due to them also being registered as sick during the first 30 days after calving. Further information about the cows included in the analysis and their diagnoses can be found in Appendix 1.

Table 1. Diagnoses and the number of cows registered for each diagnosis.

Diagnosis	Number of cows
Mastitis	28
Other diagnosis	13
Hoof problems	12
Acute puerperal metritis	11
Calving problems	9
Retentio secundiarum	5
Respiratory infection	4
Wound on teat/udder	4
Lameness	3
Ectoparasites	1
Lymphangitis	1
Uterine prolapse	1

Milk yield per day of CI (kg ECM) was calculated by dividing the total lactation yield with the lactation length in days. 22 cows were culled while lactating, Milk yield per day of CI (kg ECM) for those cows were therefore calculated by dividing the total lactation yield with the culling date expressed in DIM.

The same mixed model was used when analysing total lactation yield (kg ECM), CI (days), milk yield per day of CI (kg ECM), 305-days milk yield (kg ECM) and DPL (days). In the model, the relationship between the dependent variable and the independent variables *CI* (EXT or CONV), *breed* (Red dairy cattle; RDC or Holstein; HOL) and *part* (randomized or customised study) were analysed. The variable *farm* was included as a random factor, taking into consideration the variations between different farms. Least squares means (LS-means) were calculated for CI to be able to compare the adjusted means between the groups.

12 cows were never inseminated and therefore didn't get a NINS or FSCR. All cows with 1 NINS were categorized as '1' for FSCR in SAS, the others were categorized as '0', including the 13 cows that never got inseminated. All cows that were inseminated got pregnant at one point after receiving one or more inseminations.

When analysing NINS and FSCR a procedure GLIMMIX was used. The first model analysed the relationship between the binary response variable *FSCR* and the independent variables *breed* and *CI* by using a binary logistic regression. The second model analysed the relationship between the count response *NINS* and the independent variables *breed* and *CI*. *Farm* was included with a random effect in both models, LS-means was also calculated for CI in both models.

2.3 Experimental studies

Based on data collected from Swedish national dairy herd recording scheme (SNDRS) managed by Växa Sverige, 16 of the herds meeting the criterion were included in the first study. 14 of those also participated in the second study together with four additional herds that were recruited. The herds that were included were asked about being a part of the studies and agreed to participate. For a herd to be included in the studies they had to meet following inclusion criteria:

- >100 dairy cows in production
- Average milk production >9000 kg ECM/year
- Average CI <14 months
- System for daily milk recordings
- Reporting to SNDRS
- Located in southern Sweden.

2.3.1 Randomized study

Data covering the period August 2018-September 2021 was obtained from SNDRS and used in the randomized study. Within one month of September 1, 2018, the study had started in all 16 herds. Only purebred HOL and RDC heifers estimated to calf within six months from the study's starting date were included. The heifers were allocated a CONV (35 to 85 days) or an EXT (155 to 205 days) VWP depending on if their ear tag number was odd or even. The aim was to achieve a CI of 12 months with a CONV VWP and a CI of 16 months with an EXT VWP.

Details of the randomized study are described further in two publications written by Edvardsson Rasmussen et al. (2023a; b).

2.3.2 Customized study

In the customized study cows were allocated an EXT VWP based on their expected suitability. Suitability was determined by data obtained from SNDRS, covering the period October 2020-October 2022, and based on following three criteria:

1. Genomic persistency index (PI)
2. Disease event or difficult calving
3. Higher milk yield compared to the average herd milk yield during 4-33 DIM.

Cows with a PI>111 were expected to be suited for an EXT VWP. The cows with no registered PI were assessed based on the two remaining criteria. Disease events or a difficult calving, for example twins, reported by the farm was expected to result in the cow needing a longer recovery time before the first insemination. A milk yield during 4-33 DIM that was higher than the herd average was assumed to make the cow suitable for an EXT VWP.

If a cow met at least one of the criteria they were randomly assigned an EXT VWP of ≥185 DIM or a CONV VWP of ≤90 DIM. The cows that were not meeting any of the criteria and therefore expected not to be suitable for an EXT VWP were all assigned a CONV VWP.

Details of the customized study are described further in a publication written by Edvardsson Rasmussen et al. (2024).

3. Literature review

Milk production has steadily increased during recent decades, both in total milk yield and milk solids (Växa Sverige 2024). There is an interest in maximizing production even further through developing management and improving animal welfare (Österman et al. 2005).

The ultimate goal within the dairy industry is to have an economically efficient production, something that depends on fertility and requires high reproductive efficiency (Royal et al. 2000). However, the modern dairy cow is facing reproductive problems, as the milk yield is increasing the fertility is decreasing (Dobson et al. 2008). It has been reported that farmers are having problems with spotting cows in oestrus (Dobson et al. 2008), which could be a consequence of some cows having irregular ovarian cyclicity at the end of their VWP (Ma et al. 2022).

A management strategy that could help with problems such as compromised fertility is an extended VWP. Cows with compromised fertility could get their first insemination postponed, resulting in a longer VWP and an increased likelihood of a longer CI. With this strategy, problems with high milk production at dry off could also be solved. The number of calves born could also be reduced (Van Knegsel et al. 2022), depending on system and management, herds could be impacted both positively and negatively by this. It is important to note that an increased CI can not only be caused by a longer VWP, it can also be unvoluntary caused by a lower conception rate (Inchaisri et al. 2011).

By extending the VWP, the total lactation will get longer, something that is achievable due to modern dairy cow's persistency (Inchaisri et al. 2011). A longer lactation will prolong the period in late lactation where the milk production generally is lower, but the number of lactating days relative to dry days will increase (Österman & Bertilsson 2003; Lehmann et al. 2017; Van Knegsel et al. 2022). Persistent lactations could lead to a lower and later peak yield, but if the long term production is reasonable, it can be economically sustainable anyway (Dobson et al. 2008). It is common that heifers, with their generally flatter lactation curve, does not achieve a total lactation milk yield that is as high as a multiparous cow (Österman & Bertilsson 2003) due to them still growing at the time of the first calving (Gaillard et al. 2016). However, the flatter curve makes them more persistent and more suitable for an extended lactation (Österman & Bertilsson 2003).

With a standard CI of 12 months, the cow gets subjected to a transition period once every year (Van Knegsel et al. 2022). The onset of a new lactation can be

positive from a production perspective due to it consisting of a new peak in milk yield, but there are also negative consequences that are connected to the transition period (Van Knegsel et al. 2024). An EXT CI will result in a lower frequency of transition periods, most likely resulting in increased health, welfare and a longer productive lifespan (Van Knegsel et al. 2022). It is better to prevent than to cure and according to Dobson et al. (2008), less frequent calvings in combination with more persistent lactations will be an advantage to prevent production diseases.

Reducing the occurrence of the critical transition period could potentially increase the cows' productive lifespan, which often is one of the reasons to extend the VWP and CI (Van Knegsel et al. 2022). The productive lifespan is the period of the cow's life were she is under production, which is 34.1 months on average for a Swedish dairy cow (Växa Sverige 2024). Extending the VWP by postponing the first insemination allows for a longer recovering time from calving and negative energy balance (NEB) (Ma et al. 2022). A majority of cows are still recovering from NEB when the first semination is due after a the traditional VWP of 50 days (Inchaisri et al. 2011). By extending the VWP, the transition period is delayed (Van Knegsel et al. 2022) and results such as a more regular ovarian cyclicity can be expected (Ma et al. 2022).

3.1 Disease effects on fertility

3.1.1 Udder health

Mastitis, defined as an inflammation of the mammary gland, is one of the most frequent diseases affecting dairy cows, leading to economic losses both direct and indirect. Mastitis is mainly diagnosed by somatic cell count (SCC) and bacteria detection (Tommasoni et al. 2023). The SCC is generally high during the first weeks after parturition. There is a decrease 3-5 weeks after calving and then it stays low until the end of the lactation where a moderate increase in SCC can be observed. A longer CI can therefore come with a risk of a prolonged period at the end of lactation where the SCC are generally a bit higher (Österman et al. 2005).

Clinical mastitis is acute and short-term, it is common that the SCC increase drastically. The subclinical form of mastitis is more common, and it is said that it can be found in at least 20% of cows in commercial dairy herds worldwide (Wolfenson et al. 2015). According to Wolfenson et al. (2015), it is possible for mastitis to disrupt functions of the preovulatory follicle which results in lowered fertility.

3.1.2 Lameness & hoof disorders

One of the major production diseases in milk production is lameness (Charfeddine & Pérez-Cabal 2017) and different hoof disorders are responsible for up to 92% of

the lameness issues (Murray et al. 1996). Lameness is not only associated with production losses (Charfeddine & Pérez-Cabal 2017), reproductive performance is also reduced (Hernandez et al. 2001).

In order to gain knowledge and understanding of how lameness affects reproductive performance in dairy cows, it is essential to study hoof lesions and not only rely on visual locomotion scoring. Hoof examination during the VWP can help with understanding the association between hoof lesions in early lactation and reproductive outcomes (Omontese et al. 2020). There are several different types of hoof disorders that can be classified as infectious and non-infectious, each of them having their own special effect on the cow's performance (Charfeddine & Pérez-Cabal 2017). Hoof lesions result in an inflammatory and stress response, most likely affecting the cow's reproductive performance (Dobson et al. 2003). According to Hernandez et al (2001), cows with hoof lesions requires a significantly longer time to conceive compared to healthy cows. The longer conception time could hypothetically be explained by them showing less oestrus behaviour because of the inflammation causing them pain.

Just like many other diseases, expenses associated with claw health are often categorized into two groups: direct and indirect costs (Charfeddine & Pérez-Cabal 2017). The direct costs include treatment, time charge for veterinary and trimmer, the extra farmer time needed and the costs for discarded milk. Indirect costs are harder to quantify, but they include costs such as reduced production and a possible premature culling (Charfeddine & Pérez-Cabal 2017).

A study by Charfeddine & Pérez-Cabal (2017) demonstrated that the cow's performance and production are affected negatively by different hoof disorders such as digital dermatitis, sole ulcers and white line disease. These results were obtained by collecting data from 25 different trimmers operating in 804 HOL dairy herds in Spain between 2012 and 2014. In a Spanish herd with 64 cows, Charfeddine & Pérez-Cabal (2017) estimated that the hoof disorders led to a yearly cost of $6 700 on average, most of those costs being indirect due to production losses, impaired fertility and premature culling.

Omontese et al. (2020) studied 1639 lactating Jersey cows to evaluate if there were any associations between hoof lesions and fertility. They hypothesized that cows with pre-existing hoof lesions in early lactation would have a lower FSCR, delayed ovulation postpartum and increased risk of pregnancy loss compared to healthy cows. It was also hypothesized that cows developing new hoof lesions would increase time before getting pregnant. They found that cows with hoof lesions during early lactation had lower odds of resuming their ovarian cyclicity compared to healthy cows without hoof lesions. However, their results did not

present any differences between healthy cows and cows with hoof lesions during early lactation when it comes to FSCR, 38% and 37% respectively. Omontese et al. (2020) conclusions were therefore that the major reproductive problems in cows with hoof lesions, irrespective of type, were due to reduced ovarian cyclicity.

3.2 Economy

An improved reproductive performance within the herd will overall increase the farm's economy, when the pregnancy rate increases the economic net gain also increases (Cabrera 2014). But the economically optimal VWP varies between and within herds (Inchaisri et al. 2011; Stangaferro et al. 2018).

Out of an economic perspective, based on Dutch circumstances, Inchaisri et al. (2011) found that most cows, 63%, had an optimal VWP <8 weeks. Their result showed that only 10% of the cows had an optimal VWP longer than 9 weeks. They also discussed that the value of a calf can vary depending on the herds culling rate or a potential growth of the herd. If the herd is expanding or has a high culling rate, the calf will be of greater value. Consequently, the economic losses of a longer VWP and CI will be greater in those cases (Inchaisri et al. 2011). Because of this it is very important that decisions about the duration of VWP are made with careful consideration of herd dynamics and the productive and reproductive performance (Stangaferro et al. 2018).

Inchaisri et al. (2011) found that by extending the VWP from 6 to 10 weeks the NINS could be reduced from 1.89 to 1.76 on average. Their results showed that an EXT VWP was more likely to be economically optimal for cows with high milk persistency. Delayed first ovulation postpartum is also a factor that increased the probability of an optimal VWP ≥10 weeks. Another factor that increases the probability is if the cow is of a breed other than 100% HOL, this is due to them having lower costs that are associated with a longer VWP according to Inchaisri et al. (2011). Primiparous also have lower costs associated with a longer VWP compared to multiparous cows. Costs related to production losses, milk persistency and costs of culling were a few of the parameters taken into consideration (Inchaisri et al. 2011).

Stangaferro et al. (2018) came to the conclusion that a VWP of 60 days might be preferable for multiparous cows, only farms with high FSCR might benefit from extending the VWP beyond 60 days for primiparous cows. They also emphasized the importance of being very careful when making decisions about VWP duration. There are many complex interactions between productive and reproductive performance in dairy cows that need to be taken into consideration, especially for multiparous cows (Stangaferro et al. 2018). Van Knegsel et al. (2024) also found

in their review that factors such as milk yield, ovarian cyclicity and post-calving recovery are very complex and the interaction between them hard to understand.

The optimal VWP and CI varies a lot between herds and cows, depending on multiple factors and market circumstances. Generally, Inchaisri et al. (2011) found that a shorter VWP is the most optimal from an economic perspective, but it was also mentioned that it doesn't mean that longer CI are never profitable. For example, they found that an extension of the VWP for cows suffering from different postpartum disorders was economically preferable.

4. Results

4.1 Calving interval

In total 41 cows were on a CONV CI, 12 of those from the randomized study and 29 from the customized study. A total of 37 cows were on an EXT CI, 16 from the randomized study and 21 from the customized study. As seen in Figure 1, cows on a CONV plan had an average CI of 399 days, meanwhile cows on an EXT plan had an average CI of 468 days. The number of dry days didn't differ between CI plans (P=0.518). CONV cows had 54.6 dry days compared to EXT cows that had 56.4 dry days.

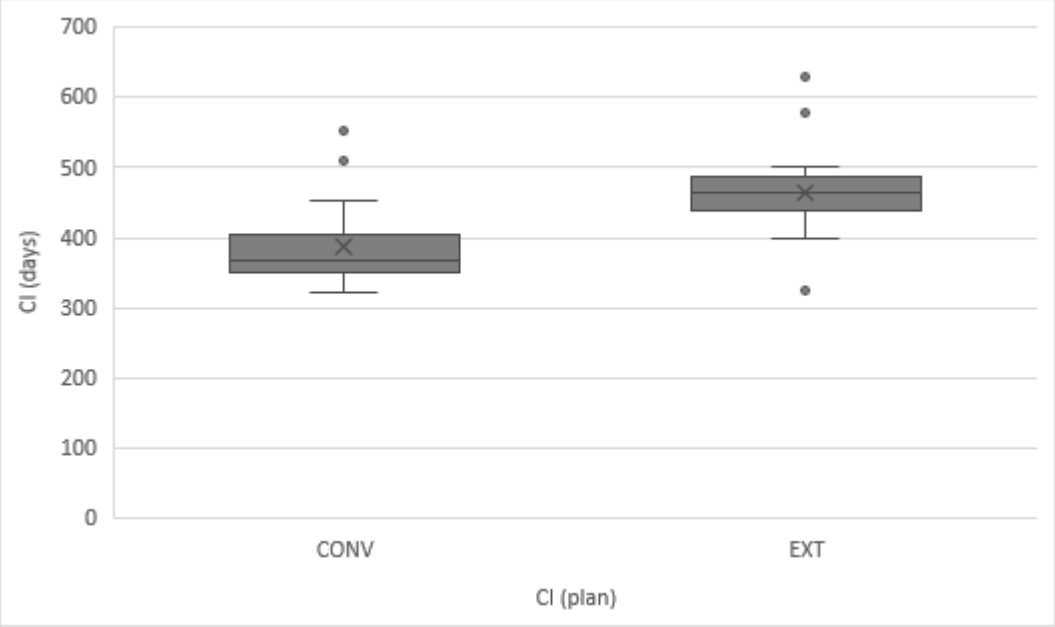

Figure 1. A boxplot showing the total number of days the cows calving intervals were on the two different treatments, CONV and EXT.

4.2 Milk

Total lactation milk yield (kg ECM) was significantly different between CI plans (P=0.007). CONV cows were estimated to have a total lactation milk yield of 10 007 kg ECM, EXT cows were estimated to have a total lactation milk yield of 12 456 kg ECM. Breed of the cow did not significantly affect this result (P=0.836) which means that there was no difference between RDC and HOL on the two different plans.

4.2.1 305-day milk yield

69 cows had a 305-day milk yield (kg ECM) registered, meaning that 9 cows were culled before 305 DIM. There was a significant difference between CONV and EXT CI plan (P=0.013), an estimation of 8944.5 kg ECM and 9991.7 kg ECM respectively. Breed did not make a significant difference (P=0.309).

4.2.2 Milk yield per day of calving interval (kg ECM)

All 78 cows were included when doing this analysis, including the 22 cows that were culled. CONV cows had an estimated milk yield per day of 26.8 kg ECM, meanwhile EXT cows had an estimated milk yield per day of 28.6 kg ECM. No significant difference could be seen between breed (P=0.462) or the two CI plans (P=0.123).

4.3 Number of inseminations (NINS)

Out of 78 cows, 65 cows had 1 or more inseminations registered. Table 2 shows how many cows that required different NINS on the two CI plans. The results from the statistical analysis show that cows on a CONV CI plan required 2.1 inseminations on average, cows on an EXT CI plan required 1.7 inseminations on average. This result shows that there is no significant difference between CI plan (P=0.249) regarding NINS. There was no significant difference between the two breeds (P=0.202) either. However, the model suggests that HOL may require fewer inseminations than RDC (relative reduction of 22.1%), but this result should, together with the result for NINS, be interpreted with caution due to the lack of significance in the result.

Table 2. Number of inseminations the cows on the two different CI plans required to become pregnant.

NINS	CONV	EXT
1	14	20
2	12	3
3	7	4
4	2	1
5	1	1

4.4 First service conception rate (FSCR)

The 65 cows that had 1 or more inseminations registered were included in the FSCR analysis. 34 cows got pregnant after 1 insemination, 69% of those were on an EXT plan and 39% were on a CONV plan. 31 of the cows required more than

1 insemination to become pregnant, 31% were on an EXT plan and 61% were on a CONV plan. CI plan played a significant role in getting this result (P=0.031). Cows on a CONV plan had a lower chance of falling pregnant after just 1 INS and therefore required more than 1 service. There was no significant difference between breeds (P=0.295) which means that the insemination results didn't differ between RDC and HOL.

Table 3. First service conception rate for the two CI plans, showing how many of the cows got pregnant after receiving one insemination.

CI plan	Yes	Yes (%)	No	No (%)
EXT	20	69	9	31
CONV	14	39	22	61

4.5 Summary

In Table 4, results from the statistical analyses are summarized, presenting both P-values and standard errors (SE).

Table 4. Summary of results from statistical analyses.

Statistical analysis	CONV	SE	EXT	SE	P
Dry days	54.6	2.54	56.4	2.60	0.518
Total milk yield (kg ECM)	10 007	626.00	12 456	643.80	0.007
305 d milk yield (kg ECM)	8944.5	295.35	9991.7	300.04	0.013
Milk yield per day of CI (kg ECM)	26.8	1.06	28.6	1.06	0.123
NINS	2.1	0.12	1.7	0.15	0.249
FSCR (%)	39	0.48	69	0.50	0.031

5. Discussion

The common practice of managing cows to calf once a year (Van Knegsel et al. 2024) is based on economical calculations made more than two decades ago (Ratnayake et al. 1998). The total milk yield of a Swedish dairy cow is approximately 2 300 kg ECM higher today compared to 25 years ago (Växa Sverige 2024). Modern dairy cows also have the capacity of maintaining a high production during extended periods of time (Knight 2005). Trying to maintain a 12 month CI with a milk production that is 28% higher compared to 25 years ago can therefore result in a few complications.

This thesis has focused on what effect an EXT CI have on milk production and fertility in primiparous cows that were sick during the first 30 days after calving, investigating if the approach of a longer CI could be more efficient. An economically efficient production depends a lot on fertility and requires high production efficiency (Royal et al. 2000), but the interaction between those two factors is very complex (Stangaferro et al. 2018). Milk yield, ovarian cyclicity and postpartum recovery are examples of a few more factors that need to be taken into consideration (Van Knegsel et al. 2024). When adding the sickness factor into the equation, the question about the optimal VWP and CI gets even harder to address. Generally, a shorter VWP has been found to be the most profitable from an economic perspective (Inchaisri et al. 2011). However, depending on earlier mentioned factors, including herd and cow characteristics, a longer CI could be profitable. If the cow is suffering from different postpartum disorders it was found to be economically preferable to prolong the CI, one of the reasons being that the cow then get the chance to resume her ovarian follicular activity properly (Inchaisri et al. 2011). This is in line with the results of this thesis due to the cows showing improved fertility without decreased production. It is beneficial for primiparous cows to receive a longer VWP and CI as they get the chance to recover from calving and sickness.

It is important to mention that a longer VWP is not always equal with a longer CI. When planning to adjust VWP and CI it is therefore important to know what you want to achieve with the management strategy. Giving the cow more time to recover from calving before the first insemination could result in the CI not getting longer due to the recovering time also improving the pregnancy rate. Within a herd with good fertility, the VWP would therefore have to be longer than the desired prolongation of the CI to have an impact on the total CI length.

The CI could also get unvoluntary longer as a cause of a low conception rate (Inchaisri et al. 2011), which hypothetically could be caused by sickness delaying

the first ovulation after calving. If a cow with good persistency requires several inseminations before getting pregnant, the revenue from milk production won't go lost if the total lactation gets longer than originally planned. For it to be economically sustainable, the revenue from the longer lactation has to cover for the costs of, for example, additional feed and the several insemination doses.

Primiparous cows generally have a lactation curve that is flatter compared to multiparous cows, which indicates that they are more persistent and therefore more suitable for an extended lactation (Österman & Bertilsson 2003). A flatter lactation curve lacks the distinct peak that can be seen in later lactations, and the total lactation yield is generally lower compared to multiparous cows. The lack of peak could motivate farmers to inseminate early to get a CONV CI so that the second lactation and its higher yield is not postponed. But depending on the cow's persistence and milk-payment circumstances, it may not be the peak in yield that pays off but the increased total lactation yield that comes with a longer lactation. Results in this thesis does show that primiparous cow's total lactation milk yield was not affected negatively when on an EXT CI plan, even though they were sick during the first 30 days after calving. The milk yield per day of CI did not differ between the EXT and CONV plans either, which also indicates that it does not affect the production negatively. These results were not compared to multiparous cows and the economic parameters were not looked into further in this thesis. However, Edvardsson Rasmussen et al. (2023b) did follow cows during both their first and second lactation and their results showed that cows on an EXT VWP plan had a higher 305 days and total lactation yield when compared to cows on a CONV plan. This was shown not only during the first lactation but also during their second lactation when there was no VWP intervention.

There is always a risk that data is registered incorrectly during collection and then impacting the results. The first criterion for being included in this statistical analysis was that the cow had to be registered as sick during the first 30 days after calving. In some cases, cows that were registered as healthy during the first 30 days after calving in the customized study, where information about diagnoses were retrieved directly from the farmers for the selection of cows, was later found to have a diagnosis registered. The biggest risk with this is that some cows are missed and excluded from the analysis by mistake. The aim is always to get a result that is as representative as possible, those cows were therefore included in the analysis because of the diagnosis even though they were initially registered as healthy.

5.1 Comparison of results

Experimental data used in this thesis was available from previous trials by Edvardsson Rasmussen et al. (2023a; b, 2024). Results in this thesis are in line with findings in previously mentioned articles, even though only cows that were sick during the first 30 days postpartum were included in the analysis.

By extending the VWP for primiparous cows, both the total lactation milk yield and the 305 d milk yield was higher when compared to primiparous cows with a CONV VWP in Edvardsson Rasmussen et al. (2023b), and the same results were found in this thesis. Both the total lactation milk yield and 305 d milk yield was higher for the sick primiparous cows with an EXT CI. That cows on an EXT CI plan had a total lactation milk yield that was higher is not a very surprising result considering that those cows had a lactation estimated to be longer compared to cows on a CONV CI. However, cows with an EXT CI had a total lactation that was almost 2400 kg ECM higher and 68 days longer, which is about 35 kg ECM per day in yield. No significant difference could be seen in Edvardsson Rasmussen et al. (2023b) or this thesis when looking at milk yield per day of CI between the two different CI plans. Edvardsson Rasmussen et al. (2023b) could only see a higher milk yield per day of CI for EXT cows during their second lactation. It is important to mention that Edvardsson Rasmussen et al (2023b) required that the cows followed their assigned VWP plan to be included. Cows on a CONV plan were considered as compliant when the VWP was 25 to 95 days, which means that the cows could deviate from the plan 10 days more or less from the original plan of 35 to 85 days. However, cows on an EXT plan were compliant if the VWP was 145 to 215 days, a deviation of 30 days less and 9 days more compared to the original plan of 155 to 205 days. All cows registered as sick during their first 30 days postpartum was included in this thesis analysis, regardless of their compliance with their assigned plan. That all cows were included could hypothetically result in EXT and CONV cows receiving the same treatment, but this was not investigated further.

Total CI, lactation length and DPL were longer for EXT cows in Edvardsson Rasmussen et al. (2023b) results during first lactation. No significant difference could be seen in the number of dry days between the two CI plans in this analysis. The non-significant result indicates that a longer CI is not equal to fewer productive days. It also indicates that the EXT cows are not dropping in yield at the end of their lactation.

When looking at reproduction Edvardsson Rasmussen et al. (2024) found that cows on an EXT CI plan during their first lactation had a better reproductive performance with a higher FSCR and a lower NINS. Results from the statistical

analysis in this thesis also shows that cows on an EXT plan have a higher FSCR. 69% of the cows only required one insemination compared to cows on a CONV plan where 61% of the cows needed more than one insemination. In average, CONV cows needed 2.1 inseminations and EXT cows needed 1.7 inseminations before getting pregnant. This indicates that EXT, with a lower NINS and higher FSCR, have better conception. But the result for NINS was not significant and should therefore be interpreted with caution. The non-significant result could be because of large variation and the small number of cows included in the analysis.

In the customized study by Edvardsson Rasmussen et al. (2024), cows suited for an EXT VWP showed a higher FSCR and a lower NINS when actually given EXT VWP. The FSCR was 60% and the NINS required was 1.67, compared to cows suited for an EXT VWP that were given a CONV VWP that had a FSCR of 45% and required 2.19 NINS. However, when compared to cows suited for a CONV VWP no differences could be found. Another study by Edvardsson Rasmussen et al. (2023a) also found that the FSCR was higher and the NINS was lower for cows on an EXT VWP during the first lactation compared to cows on a CONV VWP plan. The FSCR was 67% and 51%, respectively, and the NINS was 1.6 and 2.0.

Compared to the studies by Edvardsson Rasmussen et al. (2023a; b, 2024), the number of cows in this thesis dataset was a lot smaller. 382 cows were analysed for FSCR and NINS in one of the studies (Edvardsson Rasmussen et al. 2023a). In the other study 391 cows were analysed for FSCR and 384 cows were analysed for NINS (Edvardsson Rasmussen et al. 2024). In this thesis 78 cows were included in NINS analysis and 65 cows for the FSCR analysis. During the first lactation 349 cows were analysed for their total CI and 320 cows were analysed for lactation length and DPL. 219 cows were analysed for their total CI, 127 cows were analysed for lactation length and DPL (Edvardsson Rasmussen 2023b). Only 78 cows were analysed for those three variables. Cows from 14 different herds with 1 to 12 cows in each herd was included in the analysis. A smaller dataset generally makes it more difficult to achieve statistically significant results, which means that only very prominent effects are observable.

When analysing NINS the model suggested that HOL may require less inseminations compared to RDC, but because of the lack of significance it should be interpreted carefully. Edvardsson Rasmussen et al. (2023a, 2024) couldn't find any differences between breeds either. They looked into if the effect of a different VWP varies depending on the cow's breed, but both HOL and RDC responded equally to the different VWP treatments.

5.2 Other effects of an extended lactation

Aiming for a 12 month CI comes with its challenges. Extending the CI could be a solution to some of those problems, but it could come with its own challenges.

When implementing an EXT CI, farmers could get too eager and inseminate to early. The eagerness could be driven by the fear of not getting the cow pregnant. It could also be driven by the fear of the cow's production not being persistent enough and dropping to much at the end of the lactation. The uncertainty about the cow's persistence gets even bigger if the cow is not genomically tested. However, the result in this thesis does not indicate that this will be the case for most primiparous cows, the results when analysing DPL was not significant. This means that the primiparous cows on an EXT plan generally were persistent and held out their lactation, not drying off on their own too early. Drying off at high production levels is something that affects cow comfort and udder health negatively (Österman et al. 2005), but as the milk production is generally lower at the end of an extended lactation the cow won't get as affected when drying off. With a longer lactation the lactating days relative to dry days will also increase (Österman & Bertilsson 2003; Lehmann et al. 2017; Van Knegsel et al. 2022), which is positive from an economical perspective.

Postponing insemination could also result in a bigger proportion of the herd being in oestrus at the same time. Cows could potentially injure themself and other cows in the herd while expressing oestrus behaviour. A positive thing with this is that it could be easier to time oestrus with insemination. If the cows get to express oestrus behaviour several times it is easier for the farmer to learn how the individual cows are expressing themselves, which most likely will make it even easier for them to inseminate at the right time.

A longer CI or a wide range of different CI within the herd may result in an uneven flow of animals. To many lactating cows at the same time could lead to the occupancy being too high, which could lead to problems depending on milking system and how the barn is designed. Even if the number of calves born could be reduced with a longer CI (Van Knegsel et al. 2022), they most likely will be unevenly distributed over the year. If a large number of calves are born at the same time, it will be hard to keep them in small groups according to their age. The high occupancy in combination with the grouping can result in difficulties keeping good hygiene. It is important with hygiene and cleanliness to be able to maintain good calf health, it is therefore important that there is time for the calf boxes to be empty between batches of calves. If the hygiene is compromised the risks of the calves getting sick will increase, which will result in expensive veterinary cost. The workload for the farmer will also get affected by this,

resulting in uneven and heavy workloads during the year. But all of the previously mentioned factors could also result in positive changes within the herd, it all depends on the management preferences.

6. Conclusion

Primiparous cows that have expressed signs of sickness during the first 30 days after calving can benefit from receiving an EXT CI plan. The EXT CI plan, most likely, gives them time to recover from calving and being sick, which results in a significantly higher milk production, both in total and at 305 days, and FSCR. The number of dry days was not significantly different between the two CI plans, indicating that the productive days did not decrease when increasing the CI.

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Popular science summary

Under de senaste årtionden har mjölkavkastningen stadigt ökat, både när det gäller mängden mjölk och fett- och proteinhalt. Samtidigt som produktionsnivåerna har ökat har även reproduktionsutmaningarna och problem med fertiliteten blivit större. Ett traditionellt kalvningsintervall på 12 månader, med en frivillig väntetid på 50–60 dagar efter kalvning, har därför blivit allt svårare att upprätthålla, särskilt om kon drabbas av sjukdom efter kalvning.

I detta arbete undersöktes förstakalvare som visat tecken på sjukdom under de första 30 dagarna efter kalvning och hur deras fertilitet och mjölkproduktion påverkas av en längre frivillig väntetid och således även ett längre kalvningsintervall. Målet med arbetet var att ta reda på ifall ett längre kalvningsintervall skulle resultera i att de behöver färre inseminationer för att bli dräktiga, samtidigt som den totala mjölkproduktionen blir högre.

Resultatet visar på att antal dagar korna var sinlagda inte skiljer sig signifikant mellan kor som följde den förlänga planen (EXT) och de som följde den konventionella planen (CONV). Däremot var den totala mjölkproduktionen och produktionen under de första 305 laktationsdagarna signifikant högre för de kor som följde EXT planen. Den genomsnittliga dagliga produktionen var något högre för kor som följde EXT planen, men skillnaden var inte signifikant. Det noterades inte heller någon signifikant skillnad i antal inseminationer mellan de två planerna, även om EXT korna i genomsnitt behövde 1.7 inseminationer jämfört med 2.1 för CONV korna. 69% av korna som blev dräktiga på första inseminering var på EXT planen, en signifikant skillnad jämfört med kor på CONV planen där enbart 39% av korna blev dräktiga efter en inseminering.

Resultaten i detta arbete tyder på att förstakalvare som har visat tecken på sjukdom under den första månaden efter kalvning kan dra nytta av en förlängd väntetid innan första seminering eftersom det sannolikt ger dem mer tid för återhämtning från kalvning och sjukdom. Hur stora fördelarna är varierar dock sannolikt kraftigt mellan olika gårdar och beror troligen på en mängd olika faktorer som till exempel gårdens produktionsstrategi.

Appendix 1

Farm	Study	Breed	CI	Calving problems	Diagnosis	Treated *(days from calving)*
B	Randomized	HOL	CONV	No	Acute puerperal metritis	5
B	Customized	HOL	EXT	No	Mastitis	25
D	Customized	HOL	EXT	No	Wound on teat/udder	-
D	Customized	HOL	CONV	No	Wound on teat/udder	-
D	Customized	HOL	EXT	No	Hoof problems	15
D	Customized	HOL	CONV	No	Hoof problems	-7
D	Customized	HOL	CONV	No	Respiratory infection	21
E	Customized	HOL	CONV	No	Mastitis	16
F	Randomized	RDC	CONV	No	Mastitis	15
F	Randomized	RDC	EXT	No	Mastitis	4
F	Customized	RDC	CONV	No	Mastitis	6
F	Customized	HOL	EXT	No	Mastitis	15
F	Customized	HOL	CONV	No	Other diagnosis (blood in udder)	0
F	Customized	RDC	EXT	No	Other diagnosis (blood in udder)	-
F	Customized	RDC	CONV	No	Mastitis	-
H	Customized	RDC	EXT	No	Hoof problems	-
H	Customized	RDC	CONV	No	Hoof problems	-
I	Randomized	RDC	EXT	No	Mastitis	1
I	Randomized	RDC	EXT	No	Hoof problems	1
I	Randomized	RDC	EXT	Yes	Hoof problems	5
I	Randomized	RDC	CONV	No	Mastitis	4
I	Randomized	RDC	CONV	No	Mastitis	8
I	Randomized	RDC	CONV	No	Hoof problems	9
I	Randomized	RDC	CONV	No	Hoof problems	5
I	Randomized	RDC	EXT	No	Hoof problems	5
I	Customized	RDC	CONV	No	Hoof problems	-1
I	Customized	RDC	CONV	No	Other diagnosis	21
J	Randomized	RDC	EXT	No	Mastitis	3
J	Randomized	RDC	CONV	No	Wound on teat/udder	5
J	Randomized	HOL	EXT	No	Mastitis	5
J	Customized	HOL	EXT	No	Retentio secundiarum	11
J	Customized	HOL	CONV	Yes	Other diagnosis (reproduction disease)	10

J	Customized	RDC	CONV	No	Mastitis	-
J	Customized	HOL	CONV	No	Mastitis	8
J	Customized	HOL	CONV	No	Other diagnosis (trauma)	30
K	Customized	HOL	CONV	No	Mastitis	-
M	Randomized	RDC	EXT	No	Other diagnosis (trauma)	10
M	Randomized	RDC	CONV	No	Acute puerperal metritis	7
M	Customized	RDC	EXT	Yes	Uterine prolapse	0
M	Customized	HOL	CONV	No	Mastitis	1
M	Customized	RDC	EXT	No	Retentio secundiarum	-
M	Customized	RDC	CONV	No	Retentio secundiarum	-
N	Randomized	HOL	EXT	No	Acute puerperal metritis	2
N	Randomized	HOL	CONV	No	Ectoparasites	9
N	Randomized	HOL	EXT	No	Acute puerperal metritis	3 & 11
N	Randomized	HOL	EXT	No	Mastitis	3
N	Randomized	HOL	EXT	No	Mastitis	19
N	Randomized	HOL	EXT	No	Lameness	22
N	Randomized	HOL	EXT	No	Mastitis & other diagnosis	2 & 22
Q	Randomized	HOL	CONV	No	Hoof problem	25
Q	Randomized	HOL	EXT	No	Retentio secundiarum & acute puerperal metritis	2 & 13
Q	Randomized	HOL	CONV	No	Mastitis	22
Q	Randomized	HOL	CONV	No	Acute puerperal metritis	5 & 27
Q	Randomized	HOL	EXT	No	Mastitis	21
T	Customized	RDC	EXT	No	Hoof problem	-
T	Customized	RDC	CONV	Yes	Retentio secundiarum	-
U	Customized	HOL	EXT	Yes	Acute puerperal metritis	4
X	Customized	HOL	CONV	Yes	Respiratory infection	16
X	Customized	HOL	EXT	No	Acute puerperal metritis	3 & 10
X	Customized	HOL	CONV	Yes	Other diagnosis	0
X	Customized	HOL	EXT	Yes	Difficult calving with veterinary help	0
X	Customized	HOL	CONV	No	Acute puerperal metritis	9
X	Customized	HOL	CONV	No	Lameness	0 & 3
X	Customized	HOL	EXT	No	Mastitis	4
X	Customized	HOL	CONV	No	Lymphangitis	7
X	Customized	HOL	EXT	No	Acute puerperal metritis	3
X	Customized	HOL	CONV	No	Acute puerperal metritis	9
X	Customized	HOL	CONV	No	Acute puerperal metritis	6
X	Customized	HOL	EXT	No	Other diagnosis (trauma) & Acute puerperal metritis	0 & 5

X	Customized	HOL	CONV	No	Other diagnosis (infection)	24
X	Customized	HOL	CONV	No	Wound on teat/udder & other diagnosis (infection)	2 & 8
X	Customized	HOL	EXT	No	Mastitis	-7
X	Customized	HOL	EXT	No	Acute puerperal metritis	7
X	Customized	HOL	CONV	Yes	Respiratory infection & acute puerperal metritis	5 & 8
X	Customized	HOL	EXT	No	Other diagnosis (infection)	20
X	Customized	HOL	EXT	No	-	-
X	Customized	HOL	CONV	No	Other diagnosis	-
Z	Customized	HOL	EXT	No	Respiratory infection	11