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A randomized study on the effect of extended voluntary waiting period in primiparous dairy cows on milk yield during first and second lactation

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ABSTRACT

Extending the voluntary waiting period (VWP) for primiparous cows can have a positive impact on fertility without a negative impact on milk production per day in the calving interval (CInt). We investigated the effect of extended VWP during first lactation on milk yield (MY) during 2 consecutive lactations in primiparous cows. The study involved 16 commercial herds in southern Sweden. A total of 533 Holstein and Red dairy cattle (Swedish Red, Danish Red, Ayrshire) dairy cows were randomly assigned to a conventional 25 to 95 d VWP (n = 252) or extended 145 to 215 d VWP (n = 281). Data on calvings, inseminations, and test-day yields were retrieved from the Swedish Milk Recording System. Cows with VWP according to plan and completing 1 or 2 CInt with a second or third calving were included in the data analysis. Whole lactation and 305-d energy-corrected milk (ECM) yield were higher for the extended VWP group than the conventional VWP group in both the first lactation (12,307 vs. 9,587 and 9,653 vs. 9,127 kg ECM) and second lactation (12,817 vs. 11,986 and 11,957 vs. 11,304 kg ECM). We found no difference between the VWP groups in MY per day during the first CInt or during the first and second CInt combined, although MY per day during the second CInt was around 1.5 kg higher for cows with extended VWP than for cows with conventional VWP. Thus extended VWP for primiparous cows can be used as a management tool without compromising MY.
Key words: extended calving interval, extended lactation, lactation length, milk production

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INTRODUCTION

The effect of voluntary waiting period (**VWP**), defined as the period between calving and when the cow is permitted to receive the first insemination, on milk production and economics has been examined in several previous studies but with inconclusive results. Randomized controlled studies have generally found extended VWP to be more economically favorable relative to conventional VWP (Arbel et al., 2001; Burgers et al., 2021a), than previous simulation studies (Strandberg and Oltenacu, 1989), simulation studies based on data from voluntary extension of the VWP (Gaillard et al., 2016), and studies based on retrospective data (Holmann et al., 1984; Inchaisri et al., 2011). Since the time of those studies, average yearly milk yield (**MY**) of dairy cows has increased dramatically. Moreover, retrospective studies risk including data from involuntarily extended calving intervals (**CInt**) due to poor fertility or poor fertility management, in contrast to studies with planned extension of VWP (Niozas et al., 2019a; Rehn et al., 2000; Burgers et al., 2021b). Irrespective of study design, there is general agreement that extended VWP and longer CInt are more beneficial for primiparous cows with high yield and more persistent lactations than for multiparous cows with less persistent lactations (De Vries, 2006; Lehmann et al., 2019; Römer et al., 2020).

Planned extended VWP has been shown not to affect milk production per CInt day during the first lactation (Österman and Bertilsson, 2003; Niozas et al., 2019a; Burgers et al., 2021a) or to increase it (Arbel et al., 2001). Milk yield during early lactation after a previous lactation with extended VWP is reported to be higher (Arbel et al., 2001; Lehmann et al., 2016) or similar (Burgers et al., 2021a) to that after a previous lactation with conventional VWP. In a 3-yr study, Österman and Bertilsson (2003) monitored 1 group of cows with 3 consecutive 12-mo CInt and another group with 2 consecutive 18-mo CInt and found no difference between the groups in ECM yield per day of CInt during the second lactation.

A planned extended VWP can have several consequences. For example, improved fertility has been reported in terms of number of services per conception (Niozas et al., 2019b; Larsson and Berglund, 2000), interval between first and successful insemination (Larsson and Berglund, 2000), and first service conception rate (Niozas et al., 2019b). It may also be a strategy to decrease the overall time within their lifetime that dairy cows spend in the sensitive period around calving and dry-off (Burgers et al., 2021a) when the incidence of many diseases is highest (Ingvartsen et al., 2003). This lowers the labor requirement related to transition periods such as calving events and dry-offs and also lowers the proportions of calves, recruitment heifers, and dry cows in the herd (Lehmann et al., 2019). Extending the VWP may also lead to lower dry-off yields (Niozas et al., 2019a), which can decrease the risk of mastitis during the transition period (Rajala-Schultz et al., 2005) and has been linked to longer productive life (Römer et al., 2020). Extended VWP and CInt have been associated with an increased dry period length (Rehn et al., 2000) and higher BCS at the end of lactation, especially in multiparous cows (Burgers et al., 2021a). In a simulation study, an extended lactation for primiparous cows followed by conventional 10-mo lactations was identified as one of the most profitable alternatives (Gaillard et al., 2016). However, to our knowledge, no randomized controlled study to date has monitored primiparous cows with extended VWP in their first lactation and through a complete second lactation with no VWP intervention.

The 2 most common dairy breeds in Sweden are Swedish Holstein and Swedish Red dairy cattle. Holstein cows have higher MY, while Red dairy cattle produce milk with higher fat and protein concentrations (Växa Sverige, 2021). Our objective in this study was to investigate the effects on milk production in these 2 breeds in commercial herds during a first lactation with conventional or extended VWP and a second lactation without any VWP intervention.

MATERIALS AND METHODS

Study Design and Herd Selection Criteria

A randomized controlled trial focusing on conventional and extended VWP was carried out on commercial dairy herds in southern Sweden between August 2018 and September 2021 with ethical approval from Uppsala Ethics Committee for Animal Research, Uppsala, Sweden (protocol number 5.8.18–10126/2018). A total of 218 farmers were invited to join the study, based on data from the year 2016 to 2017 obtained from the Swedish national dairy herd recording scheme (**SNDRS**) managed by Växa Sverige. The inclusion criteria were: herds with >100 dairy cows in production and herd-average milk production of at least 9,000 kg ECM/cow per year, mean CInt less than 14 mo, and a system for daily milk recording. Nineteen herds agreed to participate, but 1 herd dropped off during the study due to miscommunication and 2 herds were excluded after analysis of insemination data due to poor compliance with the research protocol. Data from the second lactation in 1 herd were excluded because that herd was also involved in another study on extended VWP in multiparous cows.

Herd Description

The 16 participating herds had mean herd size of 165 cows (range 102 to 305), mean yearly milk production, defined as the total produced yield in the herd during the year divided by the mean number of cows in the herd during the same year, of 10,623 kg ECM (range 9,000 to 12,623 kg ECM), and mean CInt of 12.7 mo (range 11.8 to 13.8 mo) during the previous year (2016 to 2017). The herds had either automated milking systems (n = 12) or parlors (n = 4) and the cows were fed a partial mixed ration (n = 14) or TMR (n = 2). The cows were categorized as Holstein (**HOL**), Red dairy cattle (**RDC**, defined as Swedish Red, Danish Red, or Swedish Ayrshire cattle), or cross/other breeds, with a cow considered purebred if the dam and sire were of the same breed. Based on the SNDRS data for 2017 to 2018, the breed distribution in the herds was: HOL mean 50% (range 5 to 97%), RDC mean 41% (range 2 to 90%), and cross/other mean 9% (range 0 to 34%).

Cow Inclusion, Exclusion, and Intervention Regarding the Voluntary Waiting Period

The study period started within 1 mo of September 1, 2018, in all herds. Only purebred HOL and RDC heifers calving within 6 mo of the starting date of each herd were recruited for the study. The primiparous cows selected for inclusion were allocated by odd or even ear tag number to either a control group with conventional VWP of 35 to 85 d or a test group with extended VWP of 155 to 205 d. No intervention in VWP was made during the second lactation. Cows lacking insemination data or not having a complete first lactation before the end of data collection in September 2021 were excluded (n = 5).

Data Collection, Description, and Calculation of Variables

Data on breed, calvings, inseminations, 305-d lactation yields, test-day yields, and dry-off dates during 2 consecutive lactations between August 2018 and September 2021 were obtained from the SNDRS. Information about daily MY and number of milkings for individual cows was obtained from the herds' milking systems. All variables included and the way in which they were calculated are presented in Appendix Table A1. Supplemental files (documentation, metadata, and so on) are published in the Swedish National Data Service catalog (Edvardsson Rasmussen et al., 2022). Research data cannot be openly published due to restrictions in the agreement with the principal owner of the data, Växa Sverige. The figures were made using GraphPad Prism version 9.5.0 (GraphPad Prism, 2022).

Variable Inclusion Criteria

Three inclusion criteria were used, depending on the variable under investigation. These were: VWP according to plan, complete lactation, and sufficient daily MY records.

Voluntary Waiting Period According to Plan and Complete Lactation. The cows were considered to have VWP according to plan when the instruction regarding number of days from calving to the first insemination interval was followed, allowing a deviation of 10 d from the plan. Thus for cows in the conventional group, VWP of 25 to 95 DIM was considered to comply with the plan, while for the cows in the extended VWP group, VWP of 145 to 215 DIM was considered to be in compliance. Cows that had their second or third calving before the end of data collection in September 2021 were considered to have a complete first or second lactation, respectively. Both these inclusion criteria were applied for all variables studied.

Sufficient Daily Milk Yield Records. Daily MY records were considered sufficient if there were less than 50% missing daily yield records in total, no more than the first 40 d of lactation missing, and no more than the last 60 daily yields in the lactation missing. These inclusion criteria were applied for lactation length, dry period length (**DPL**), DPL category, MY at test milking 50 to 20 d before dry-off, and lactation curve calculations. For cows with between 2 and 60 daily yield records missing in the end of lactation, the DPL and DPL category was calculated as described in Appendix Table A1.

Statistical Analysis

Initial data handling was performed in Microsoft Excel 2016 and statistical analysis was performed in R software (R Core Team, 2014), using R studio version R-4.1.2 (RStudio Team, 2021). The confidence level was set at $P < 0.05$. All models included VWP group (2 levels) and breed (2 levels) as fixed factors and the random effect of herd (16 and 15 levels in first and second lactation, respectively). Interaction between VWP group and breed was also tested as a fixed factor and was removed from the models if not significant.

For continuous variables with an approximate normal distribution of residuals, i.e., MY variables, CInt, lactation length, and DPL, linear mixed models were fitted by restricted maximum likelihood using the lmer function from the packages lme4 and emmeans in R (Bates et al., 2022; Lenth et al., 2022). The results of the models were analyzed with Type III Analysis of Variance with Satterthwaite's method to obtain P-values, and the results are presented as least squares means (LSM) ± standard error of the mean (SEM).

Table 1. First and second lactation calving interval, lactation length, dry period length, and milk yield (MY) at test milking (TM) 50 to 20 d before dry-off (DO; LSM ± SEM) for cows with conventional (CONV) or extended (EXT) voluntary waiting period (VWP) for the 2 breeds Holstein (HOL) and Red dairy cattle (RDC)

		VWP group			Breed		
Item	n	CONV	EXT	P-value	HOL	RDC	P-value
First lactation							
Calving interval (d)	349	$368^{b} \pm 3.7$	$462^{a} \pm 3.9$	<0.001	413 ± 3.7	416 ± 4.4	0.60
Lactation length (d)	320	$311^{b} \pm 4.2$	$398^{a} \pm 4.3$	<0.001	353 ± 4.1	355 ± 5.0	0.67
Dry period length (d)	320	$56.2^{b} \pm 2.6$	$62.6^{a} \pm 2.6$	<0.001	59.8 ± 2.6	59.0 ± 2.9	0.72
MY TM before DO (kg)	285	$25.9^{a} \pm 0.94$	$24.0^{b} \pm 0.95$	<0.001	$26.2^{a} \pm 0.93$	$23.7^{b} \pm 1.0$	0.003
Second lactation							
Calving interval (d)	219	377 ± 6.2	386 ± 6.6	0.13	$390^{a} \pm 6.6$	$373^{b} \pm 7.4$	0.03
Lactation length (d)	127	315 ± 7.8	331 ± 8.7	0.06	332 ± 8.2	314 ± 9.3	0.06
Dry period length (d)	127	58.8 ± 2.1	58.1 ± 2.4	0.75	58.2 ± 2.2	58.7 ± 2.5	0.84
MY TM before DO (kg)	106	27.3 ± 1.0	27.2 ± 1.1	0.93	$30.1^{a} \pm 1.0$	$24.4^{b} \pm 1.2$	<0.001

[a,b]Mean values within rows with different superscripts differ significantly ($P < 0.05$).

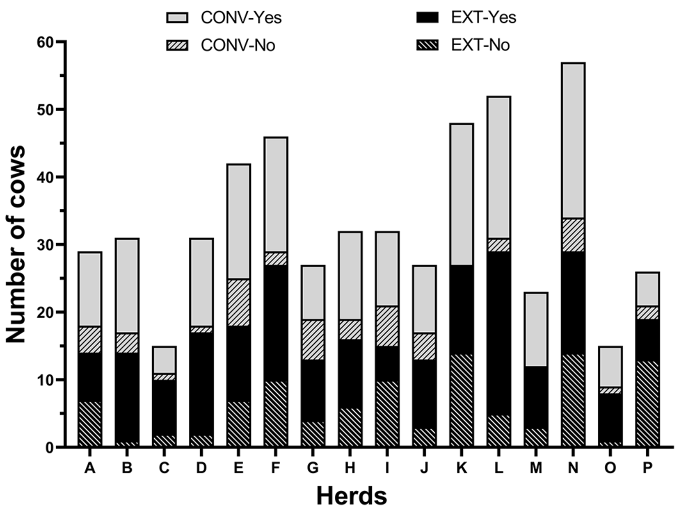

Figure 1. Number of cows that finally received (Yes) or did not receive (No) the planned voluntary waiting period (VWP) in each VWP group conventional (CONV) and extended (EXT) in each herd.

For the binary variable, DPL category, a generalized binomial linear mixed model was fitted by Laplace approximation, using the glmer function in the packages lme4 and emmeans in R (Bates et al., 2022; Lenth et al., 2022). The model was analyzed with analysis of deviance using type II Wald chi-square tests for hypothesis testing. Numbers of cows in the short and long DPL subgroups were compared with the number of cows with moderate DPL.

RESULTS

The initial number of cows recruited for the study was 533, of which 252 cows were included in the control group with conventional VWP and 281 cows were included in the test group with extended VWP. The number of cows per lactation and VWP group following each combination of inclusion criteria is presented in Appendix Table A2, and the number of cows following the planned VWP in each VWP group in each herd is presented in Figure 1. Breed distribution between planned VWP groups in each lactation is shown in Appendix Table A3. The interaction between VWP and breed was not significant and was removed from all models.

Effect of Voluntary Waiting Period on Calving Interval, Lactation Length, and Dry Period Length

For the cows in the extended VWP group, CInt, lactation length, and DPL were all longer during their first CInt than for the group with conventional VWP (Table 1). When comparing the proportion of cows in different DPL categories (short, moderate, or long dry period), we found that the proportion of cows with a long dry period in their first CInt was higher in the extended than in the conventional VWP group. There was no significant difference between the VWP groups regarding the proportion of cows with short DPL (Table 2). During the second lactation, CInt, lactation length, DPL, and DPL category did not differ significantly between the 2 VWP groups (Tables 1 and 2).

Effect of Voluntary Waiting Period on Milk and Energy-Corrected Milk Yield

Whole lactation (**WL**) yield during the first lactation was 28% greater for the extended VWP group than for the conventional group, and the former group also had 6% higher 305-d yield. However, when yield was calculated per day of CInt, there was no difference be-

Table 2. Percent and prevalence (n/N) of short and long dry period in each lactation for cows with conventional (CONV) or extended (EXT) voluntary waiting period (VWP) for the 2 breeds Holstein (HOL) and Red dairy cattle (RDC)

		VWP					Breed				
		CONV		EXT			HOL		RDC		
Item	N_{tot}[1]	%	(n/N)	%	(n/N)	P-value	%	(n/N)	%	(n/N)	P-value
First lactation											
Short dry period[2]	277	8	(13/158)	5	(6/119)	0.33	5	(9/181)	10	(10/96)	0.10
Long dry period[3]	301	9[b]	(15/160)	20[a]	(28/141)	0.002	13	(25/197)	17	(18/104)	0.35
Second lactation											
Short dry period[2]	111	3	(2/64)	6	(3/47)	0.73	3	(2/66)	7	(3/45)	0.79
Long dry period[3]	122	13	(9/71)	14	(7/51)	0.86	12	(9/73)	14	(7/49)	0.61

[a,b]Values (%) within rows with different superscripts differ significantly ($P < 0.05$).

[1]N_{tot} = total number of cows included in each model.

[2]Less than 40 d dry, n = number of cows with short dry period, N = sum of cows with short and moderate dry period length. Moderate dry period length = (40–70 d, lactation 1: N = 145; lactation 2: N = 62).

[3]More than 70 d dry, n = number of cows with long dry period, N = sum of cows with long and moderate dry period length.

Table 3. First and second lactation 305-d lactation yield, whole lactation (WL) yield, and average milk yield (MY) per day in each calving interval (CInt) and during 2 consecutive CInt (kg, LSM ± SEM) for cows with conventional (CONV) or extended (EXT) voluntary waiting period (VWP) for the 2 breeds Holstein (HOL) and Red dairy cattle (RDC)

		VWP			Breed		
Item	n	CONV	EXT	*P*-value	HOL	RDC	*P*-value
First lactation							
305-d ECM	347	9,127^{b} ± 228	9,653^{a} ± 230	<0.001	9,488 ± 231	9,291 ± 244	0.28
305-d MY	347	8,882^{b} ± 230	9,492^{a} ± 233	<0.001	9,474^{a} ± 234	8,901^{b} ± 249	0.003
WL ECM	349	9,578^{b} ± 325	12,307^{a} ± 329	<0.001	11,070 ± 331	10,816 ± 352	0.36
WL MY	349	9,279^{b} ± 306	11,872^{a} ± 311	<0.001	10,926^{a} ± 312	10,225^{b} ± 335	0.01
Daily ECM	349	26.1 ± 0.75	26.7 ± 0.76	0.15	26.7 ± 0.76	26.1 ± 0.80	0.30
Daily MY	349	25.3 ± 0.73	25.7 ± 0.74	0.30	26.3^{a} ± 0.74	24.7^{b} ± 0.78	0.004
Second lactation							
305-d ECM	219	11,304^{b} ± 241	11,957^{a} ± 253	0.002	11,973^{a} ± 253	11,288^{b} ± 281	0.02
305-d MY	219	11,061^{b} ± 226	11,778^{a} ± 240	0.001	12,115^{a} ± 239	10,723^{b} ± 268	<0.001
WL ECM	219	11,986^{b} ± 274	12,817^{a} ± 294	0.005	12,907^{a} ± 289	11,896^{b} ± 330	0.008
WL MY	219	11,659^{b} ± 253	12,527^{a} ± 274	0.003	12,963^{a} ± 266	11,223^{b} ± 307	<0.001
Daily ECM	219	31.8^{b} ± 0.70	33.3^{a} ± 0.73	0.01	33.2 ± 0.73	31.9 ± 0.81	0.10
Daily MY	219	30.9^{b} ± 0.68	32.6^{a} ± 0.71	0.007	33.3^{a} ± 0.71	30.2^{b} ± 0.79	<0.001
Both lactations combined							
Daily ECM	219	29.2 ± 0.70	30.1 ± 0.72	0.07	30.1 ± 0.72	29.2 ± 0.78	0.21
Daily MY	219	28.4 ± 0.67	29.2 ± 0.69	0.10	30.0^{a} ± 0.69	27.7^{b} ± 0.75	<0.001

^{a,b}Mean values within rows with different superscripts differ significantly ($P < 0.05$).

tween the groups (Table 3). The lactation curves for first-parity cows in the 2 VWP groups are shown in Figure 2. During the second lactation, the extended VWP group had 5 to 7% higher WL yield, 305-d yield, and yield per CInt day than the conventional VWP group (Table 3). The lactation curves for second-parity cows in the 2 VWP groups are shown in Figure 3. Comparisons of average yield per day during the 2 CInt combined revealed that this did not differ significantly between the 2 VWP groups (Table 3).

Effect of Breed

In their first lactation, HOL cows had around 6% higher MY (305d MY, WL, daily MY) than RDC cows, but ECM yields did not differ significantly between the breeds. During the second lactation, HOL cows had higher WL yield, 305-d yield, and MY per CInt day than RDC cows, but there was no significant difference in ECM yield per CInt day. Average MY per day during the 2 CInt combined was 8% higher for HOL than

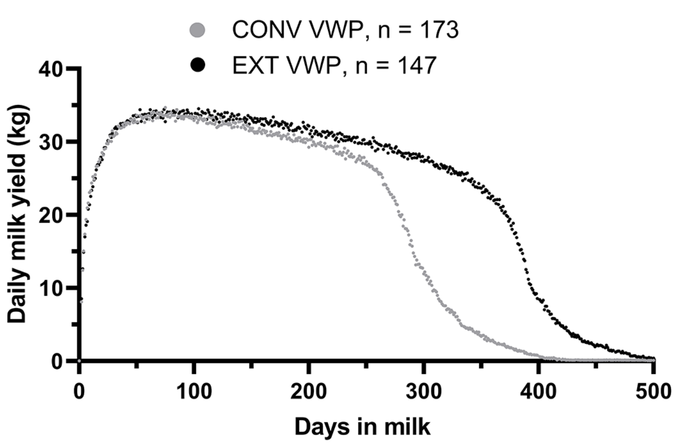

Figure 2. Average daily milk yield per DIM during the complete first lactation for cows with a conventional (CONV) voluntary waiting period (VWP; gray, n = 173) or extended (EXT) VWP (black, n = 147) during their first lactation. Based on data from cows with sufficient daily milk yield records, dried-off cows were included with 0 kg yield per day.

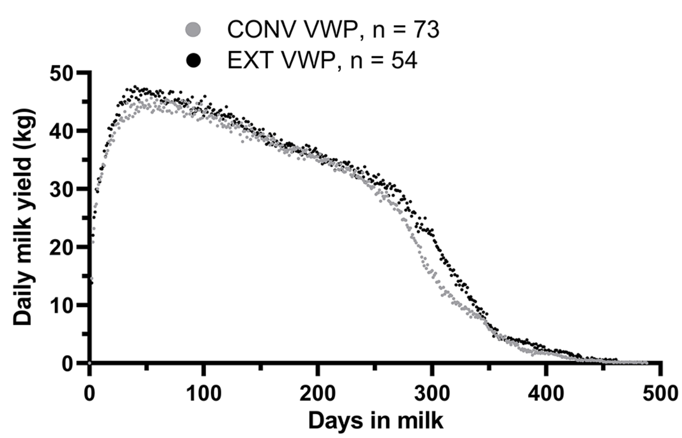

Figure 3. Average daily milk yield per DIM during the complete second lactation for cows with a conventional (CONV) voluntary waiting period (VWP; gray, n = 73) or extended (EXT) VWP (black, n = 54) during their first lactation. Based on data from cows with sufficient daily milk yield records, dried-off cows were included with 0 kg yield per day.

for RDC cows, but there was no difference between the breeds in ECM yield (Table 3).

In terms of CInt, lactation length, DPL, and proportions of cows in different DPL categories (short, moderate, or long dry period), there was no significant difference between the breeds in the first lactation, but during the second lactation HOL cows had 5% longer CInt (Tables 1 and 2). HOL cows had 11% higher MY at the last test milking before dry-off than RDC cows in the first lactation and 23% higher in the second lactation (Table 1).

DISCUSSION

This study investigated milk production during the first lactation with conventional or extended VWP and the following full lactation without a VWP intervention. To our knowledge, no random controlled trial has done this before at a large scale in commercial herds.

The study was performed on 16 relatively high-yielding herds (9,000 to 12,623 kg average yearly milk production) in southern Sweden. These herds had 102 to 305 cows with reasonable average CInt before the study (<14 mo) and varying management routines. As the study was performed on commercial herds, there is a possibility that herd managers may have treated the cows differently depending on the VWP group to which they were allocated as indicated by Figure 1. We checked whether average MY during the first 4 to 33 d of lactation differed between groups of cows not following the planned conventional and extended VWP and found no difference (results not shown). The results thus revealed no indication of obvious systematic bias among cows that did not follow the intended VWP treatment in that regard. Another possible bias related to commercial herds is possible inconsistency in data reported to the SNDRS. To mitigate this problem and other deviations in herd-related management routines, we included herd as a random factor in all statistical models.

As expected, because lactations were longer, extended VWP resulted in higher WL yield, as also reported by Lehmann et al. (2016) and Burgers et al. (2021b). Moreover the 305-d yield was higher during the first lactation, probably due to a delay in the negative effect of pregnancy on MY (as seen in Figure 2). Our results for ECM yield per day in the first CInt, which were generally not different between VWP groups, correspond well to previous findings for primiparous cows on ECM per CInt day (Österman and Bertilsson, 2003; Niozas et al., 2019a; Burgers et al., 2021a) or in extended VWP (Arbel et al., 2001; Lehmann et al., 2016).

On comparing MY per day during the second CInt, the cows with extended VWP in their first lactation produced around 1.6 kg more milk per day than the cows with conventional VWP. As mentioned, we found few other random controlled studies investigating the effect of extended VWP on the subsequent lactation and none following a complete second lactation without a VWP intervention. Österman and Bertilsson (2003) studied 2 consecutive CInt, both either conventional (12 mo) or extended (18 mo) and found that the difference between the groups in terms of WL yield increased during the second lactation, with higher yield in cows with extended CInt, but no difference between the groups on comparing ECM per CInt day in either lactation. In studies on early subsequent lactation, Arbel et al. (2001) and Lehmann et al. (2016) observed increased yield per day during the first 80 and 150 d, respectively, for cows with extended VWP in their first lactation. In contrast, Burgers et al. (2021a) found decreased MY per day during the first 42 d in the following lactation for cows with extended VWP in their first lactation, but no difference in fat- and protein-corrected milk. Those authors concluded that 42 d might be too short a period for cows to show their potential for higher yield.

According to Lehmann et al. (2016), a possible reason for the observed higher second lactation yield in cows with extended VWP might be that these cows are more mature in early second lactation, meaning that they may need less energy for growth and can allocate more energy to milk production instead. However, our observations indicated that a higher proportion of cows allocated to extended VWP were culled due to low milk production during the first lactation (data not shown). Thus, it is possible that the observed higher yield in the second lactation was an artifact related to a higher rate of culling of cows with lower yield potential.

From a farmer's perspective, it is interesting to compare average yield per day during the first and second lactations combined. We found no significant difference between the VWP groups, which suggests that the long dry period for cows with extended VWP in their first lactation was compensated for by higher total yield in both lactations or a lower proportion of dry days.

As a consequence of extended VWP, both CInt and lactation length were prolonged in the first lactation, but there was no difference between the VWP groups in the second lactation. Regarding DPL, we found a higher frequency of extended VWP cows in the long DPL category, in line with previous findings (Österman and Bertilsson, 2003; Lehmann et al., 2016). Milk yield at the last test milking before dry-off, which was investigated here as a measure of dry-off yield before the application of dry-off routines, was 1.9 kg lower in the extended VWP group than in the group with conventional VWP in the first lactation, in agreement with findings in Niozas et al. (2019a).

It is well established that HOL cows generally have higher ECM yield than RDC cows, but in the present study there was no such difference between the breeds in their first lactation. This was supported by unpublished data indicating that the difference in ECM yield between the breeds was less prominent during their first lactation (E. Strandberg, Swedish University of Agricultural Science, Uppsala, Sweden, personal communication, 2022). In addition, there was no interaction between breed and VWP, which suggests that both breeds are equally suited to extended VWP. However, HOL cows produced more milk before dry-off than RDC cows, so reduced MY before dry-off may be an incentive to extend VWP for HOL cows. Additionally, we found that HOL cows had a longer second CInt than RDC cows. This may be because the HOL cows had higher yield and farmers might therefore be more willing to delay the first insemination for these cows. It may also be because higher yield is linked to longer first-to-successful insemination interval (Römer et al., 2020).

The results for CInt and lactation lengths and WL yields were consistent with the lactation curves derived from daily MY in both lactations (Figure 2 and Figure 3), although the curves were based on fewer animals because only lactations with sufficient daily yield recordings were included. In the first lactation (Figure 2), an effect of pregnancy on daily yield was observed from about 150 DIM for the conventional VWP group, in line with findings by Österman and Bertilsson (2003).

Our results support previous claims that extended VWP in primiparous cows does not have a negative impact on individual milk production (Rehn et al., 2000; Kok et al., 2019; Lehmann et al., 2019). And we found that cows with extended VWP had fewer unproductive days: 13.5% (62.6 out of 462 d) vs. 15% (56.2 out of 368 d) of the first CInt than cows with conventional VWP (Table 1). Therefore, it may be beneficial to extend VWP, especially when taking account of other potential advantages such as improved fertility (Larsson and Berglund, 2000; Niozas et al., 2019b), possibly better health due to fewer transition periods with high disease frequency (Ingvartsen et al., 2003), lower MY at dry-off (Rajala-Schultz et al., 2005; Niozas et al., 2019a), and a longer productive life (Gaillard et al., 2016; Römer et al., 2020). However, when applying extended VWP in practice, consideration has to be given to what this means for herd dynamics. Longer VWP leads to more lactating cows, a lower need for recruitment heifers, fewer dry cows, and fewer calves born (Lehmann et al., 2019).

CONCLUSIONS

Cows with extended VWP during their first lactation had higher 305-d and whole lactation yield than cows with conventional VWP, not only in the first lactation when VWP differed for the 2 groups, but also in their second lactation without a VWP intervention. We found no difference between the VWP groups regarding yield per CInt day in the first CInt or in the 2 CInt combined. In the second CInt, yield per day was higher for cows with extended VWP during their first lactation. Regarding breed, HOL cows generally had higher MY than RDC cows, but ECM yield did not differ between the breeds during the first lactation and there were no interactions between VWP and breed. These results improve understanding of the effect of extended VWP on milk production during 2 consecutive lactations and can have implications for management decisions regarding VWP for primiparous cows. To conclude, extending the VWP for primiparous cows can be used as a management tool without compromising MY.

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REFERENCES

Arbel, R., Y. Bigun, E. Ezra, H. Sturman, and D. Hojman. 2001. The effect of extended calving intervals in high lactating cows on milk production and profitability. J. Dairy Sci. 84:600–608. https://doi.org/10.3168/jds.s0022-0302(01)74513-4.

Bates, D., M. Maechler, B. Bolker, S. Walker, R. H. B. Christensen, H. Singmann, B. Dai, F. Scheipl, G. Grothendieck, P. Green, J. Fox, A. Bauer, and P. N. Krivitsky. 2022. lme4: Linear Mixed-Effects Models using "Eigen" and S4 (1.1-29). Accessed Apr. 7, 2022. https://cran.r-project.org/src/contrib/Archive/lme4/.

Burgers, E. E. A., A. Kok, R. M. A. Goselink, H. Hogeveen, B. Kemp, and A. T. M. van Knegsel. 2021a. Effects of extended voluntary waiting period from calving until first insemination on body condition, milk yield, and lactation persistency. J. Dairy Sci. 104:8009–8022. https://doi.org/10.3168/jds.2020-19914.

Burgers, E. E. A., A. Kok, R. M. A. Goselink, H. Hogeveen, B. Kemp, and A. T. M. van Knegsel. 2021b. Fertility and milk production on commercial dairy farms with customized lactation lengths. J. Dairy Sci. 104:443–458. https://doi.org/10.3168/jds.2019-17947.

De Vries, A. 2006. Economic value of pregnancy in dairy cattle. J. Dairy Sci. 89:3876–3885. https://doi.org/10.3168/jds.S0022-0302(06)72430-4.

Edvardsson Rasmussen, A., R. Båge, E. Strandberg, M. Åkerlind, K. Holtenius, and C. Kronqvist. 2022. INDILACT – Extended voluntary waiting period in primiparous dairy cows. Part 1: Randomized controlled trial. Version 1.0. Accessed Nov. 14, 2022. https://snd.gu.se/en/catalogue/study/2022-131.

Gaillard, C., O. Martin, P. Blavy, N. C. Friggens, J. Sehested, and H. N. Phuong. 2016. Prediction of the lifetime productive and reproductive performance of Holstein cows managed for different lactation durations, using a model of lifetime nutrient partitioning. J. Dairy Sci. 99:9126–9135. https://doi.org/10.3168/jds.2016-11051.

GraphPad Software. 2022. GraphPad Prism, version 9.5.0 for Windows. Accessed Nov. 9, 2022. www.graphpad.com.

Holmann, F. J., C. R. Shumway, R. W. Blake, R. B. Schwart, and E. M. Sudweeks. 1984. Economic value of days open for Holstein cows of alternative milk yields with varying calving intervals. J. Dairy Sci. 67:636–643. https://doi.org/10.3168/jds.S0022-0302(84)81349-1.

Inchaisri, C., R. Jorritsma, P. L. A. M. Vos, G. van der Weijden, and H. Hogeveen. 2011. Analysis of the economically optimal voluntary waiting period for first insemination. J. Dairy Sci. 94:3811–3823. https://doi.org/10.3168/jds.2010-3790.

Ingvartsen, K. L., R. J. Dewhurst, and N. C. Friggens. 2003. On the relationship between lactational performance and health: Is it yield or metabolic imbalance that cause production diseases in dairy cattle? A position paper. Livest. Prod. Sci. 83:277–308. https://doi.org/10.1016/S0301-6226(03)00110-6.

Kok, A., J. O. Lehmann, B. Kemp, H. Hogeveen, C. E. Van Middelaar, I. J. M. De Boer, and A. T. M. Van Knegsel. 2019. Production, partial cash flows and greenhouse gas emissions of simulated dairy herds with extended lactations. Animal 13:1074–1083. https://doi.org/10.1017/S1751731118002562.

Larsson, B., and B. Berglund. 2000. Reproductive performance in cows with extended calving interval. Reprod. Domest. Anim. 35:277–279. https://doi.org/10.1046/j.1439-0531.2000.00278.x.

Lehmann, J. O., J. G. Fadel, L. Mogensen, T. Kristensen, C. Gaillard, and E. Kebreab. 2016. Effect of calving interval and parity on milk yield per feeding day in Danish commercial dairy herds. J. Dairy Sci. 99:621–633. https://doi.org/10.3168/jds.2015-9583.

Lehmann, J. O., L. Mogensen, and T. Kristensen. 2019. Extended lactations in dairy production: Economic, productivity and climatic impact at herd, farm and sector level. Livest. Sci. 220:100–110. https://doi.org/10.1016/j.livsci.2018.12.014.

Lenth, R. V., P. Buerkner, M. Herve, J. Love, F. Miguez, H. Riebl, and H. Singmann. 2022. emmeans: Estimated marginal means, aka least-squares means (1.7.4-1). Accessed May 15, 2022. https://cran.r-project.org/src/contrib/Archive/emmeans/.

Niozas, G., G. Tsousis, C. Malesios, I. Steinhöfel, C. Boscos, H. Bollwein, and M. Kaske. 2019a. Extended lactation in high-yielding dairy cows. II. Effects on milk production, udder health, and body measurements. J. Dairy Sci. 102:811–823. https://doi.org/10.3168/jds.2018-15117.

Niozas, G., G. Tsousis, I. Steinhöfel, C. Brozos, A. Römer, S. Wiedemann, H. Bollwein, and M. Kaske. 2019b. Extended lactation in high-yielding dairy cows. I. Effects on reproductive measurements. J. Dairy Sci. 102:799–810. https://doi.org/10.3168/jds.2018-15115.

Österman, S., and J. Bertilsson. 2003. Extended calving interval in combination with milking two or three times per day: Effects on milk production and milk composition. Livest. Prod. Sci. 82:139–149. https://doi.org/10.1016/S0301-6226(03)00036-8.

Rajala-Schultz, P. J., J. S. Hogan, and K. L. Smith. 2005. Short communication: Association between milk yield at dry-off and probability of intramammary infections at calving. J. Dairy Sci. 88:577–579. https://doi.org/10.3168/jds.S0022-0302(05)72720-X.

R Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing.

Rehn, H., B. Berglund, U. Emanuelson, G. Tengroth, and J. Philipsson. 2000. Milk production in Swedish dairy cows managed for calving intervals of 12 and 15 months. Acta Agric. Scand. Sect. A Anim. Sci. 50:263–271. https://doi.org/10.1080/090647000750069458.

Römer, A., A. Boldt, and J. Harms. 2020. One calf per cow and year: Not a sensible goal for high-yielding cows from either an economic or an animal welfare perspective. Landbauforsch. J. Sustain. Org. Agric. Syst. 70:39–44. https://doi.org/10.3220/LBF1595846539000.

RStudio Team. 2021. RStudio (1.4.1743-4). Accessed Aug. 5, 2022. https://dailies.rstudio.com/version/1.4.1743-4/.

Sargent, F. D., V. H. Lytton, and O. G. Wall Jr.. 1968. Test interval method of calculating dairy herd improvement association records. J. Dairy Sci. 51:170–179. https://doi.org/10.3168/jds.S0022-0302(68)86943-7.

Sjaunja, L. O., L. Baevre, L. Junkkarinen, and J. Pedersen. 1990. A Nordic proposal for an energy corrected milk (ECM) formula. Pages 156–157 in 27th Sess. ICRPMA.

Strandberg, E., and P. A. Oltenacu. 1989. Economic consequences of different calving intervals. Acta Agric. Scand. 39:407–420. https://doi.org/10.1080/00015128909438534.

Växa Sverige. 2021. Cattle statistics 2021. Husdjursstatistik. Accessed Aug. 5, 2022. https://www.vxa.se/fakta/styrning-och-rutiner/mer-om-mjolk/statistik/.

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APPENDIX

Table A1. Variables used in the analysis and the method of calculation

Variable	Description/calculation
305-d yield	Data on 305-d lactation milk, fat, and protein yields retrieved from the Swedish national dairy herd recording scheme (SNDRS).
Calving interval (CInt)	Number of days between 2 consecutive calving dates.
Daily milk yield (DMY)	Sum of individual milk record yields (kg) from the milking systems for a given DIM. Outliers were defined as DMY values more than 2 SD from the 2-wk mean and removed. Missing values between recorded values were interpolated based on existing DMY. Missing DMY at the end of lactation were calculated based on the mean lactation curve for all cows in each VWP group with sufficient DMY at the end of lactation for first and second lactation, respectively. Daily yields were used to calculate the lactation curves for each VWP group.
Dry period length (DPL)	Calving interval minus lactation length.
DPL category	Short defined as less than 40 d, moderate defined as 40 to 70 d, or long defined as more than 70 d.
ECM yield	Calculated according to the equation by Sjaunja et al. (1990): kg ECM = kg MY × {[38.3 × fat (g/kg) + 24.2 × protein (g/kg) + 783.2]/3,140}
Lactation length	The interval between calving and the last day of the lactation (see below).
Last day of lactation (used to calculate lactation length and dry period)	The dry-off date recorded in SNDRS was used as the last day of lactation if this occurred later than the date of the last test milking *and* if the date of the last test milking occurred later than the date of the last recorded daily yield. Otherwise, the date of either the last recorded daily yield *or* the last test milking was used, whichever was the latest.
Milk and ECM yield per calving interval day	Whole lactation yield divided by calving interval.
Milk and ECM yield per day during 2 calving intervals	Sum of the 2 whole lactation yields, divided by sum of the 2 calving intervals.
Milk yield (MY) at test milking before dry-off	Daily milk yield at the test milking between 50 and 20 d before dry-off. If the cow had more than 1 test milking in this period, data for the test milking closest to 50 d before dry-off were used.
Whole lactation yield	Whole lactation milk, fat, and protein yields calculated based on test milkings, using the test interval method (Sargent et al., 1968). Dry-off dates reported to SNDRS were used to define end of lactation in these calculations.

Table A2. Number of cows with conventional (CONV) or extended (EXT) voluntary waiting period (VWP) following the different inclusion criteria and combinations of inclusion criteria applied in data analysis[1]

	Lactation 1			Lactation 2		
Inclusion criteria	CONV VWP (n = 252)	EXT VWP (n = 281)	Total lact. 1 (n = 533)	CONV VWP in lact. 1 (n = 191)	EXT VWP in lact. 1 (n = 188)	Total lact. 2 (n = 379)
VWP according to plan (VWP OK)	205	179	384	168	139	307
Complete lactation (compl.)	210	211	421	140	125	265
Daily milk yields OK (MY OK)	207	223	430	107	91	198
<50% missing daily yields	228	245	473	129	113	242
<40 missing daily yields in early lactation	248	278	526	160	131	291
<60 missing daily yields at the end of lactation	219	235	454	129	122	251
VWP OK + compl.	187	162	349	123	96	219
VWP OK + compl. + available 305-d yield	186	161	347	123	96	219
VWP OK + compl. + MY OK	173	147	320	73	54	127
VWP OK + compl. + MY OK + available test milking yield 50–20 d before dry-off	151	134	285	59	47	106
VWP not OK + MY OK	25	63	88	12	20	32

[1]Lact. = lactation.

Table A3. Number of cows divided by breed [Holstein (HOL) or Red dairy cattle (RDC)] with a planned conventional (CONV) or extended (EXT) voluntary waiting period (VWP) in the first and second lactations

	CONV		EXT		Total	
Lactation	HOL	RDC	HOL	RDC	HOL	RDC
First lactation	146	106	181	100	327	206
Second lactation	109	82	115	73	224	155