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Analysis of the calving-to-conception interval variation and it relation to milk production traits of dairy cows

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Intensive selection for milk production has resulted in unfavorable genetic correlations with fertility, contributing to longer calving intervals, increased insemination rates, higher culling levels, and rising costs of reproductive management. This study examined the effects of genetic and environmental factors on the calving-to-conception interval and its relationship with milk productivity traits in Holstein cows. The analysis was based on data from cows that calved at PJSC 'Plemzavod Stepnoy' in Zaporizhzhia region, Ukraine, between 2014 and 2017. For each animal, 305-d milk yield, milk fat percentage, and the calving-to-conception interval were recorded and analyzed using the General Linear Model. The results showed that parity, year and season of calving significantly influenced the calving-to-conception interval, whereas the effect of sire was not significant. Younger cows generally conceived sooner after calving than older cows. Over the study period, there was a clear tendency toward shorter calving-to-conception intervals, suggesting improvement in reproductive performance. Cows calving in summer and autumn also had shorter intervals than those calving in winter or spring. The joint analysis of parity and the calving-to-conception interval indicated that reproductive efficiency was closely related to milk yield and composition. Cows with moderate calving-to-conception intervals (91–120 d) produced more milk of slightly higher quality than those with shorter or longer intervals. Overall, the findings highlight the importance of managing reproductive cycles to optimize both fertility and milk productivity in Holstein herds under the production conditions of southern Ukraine.

Keywords: milk production; fertility in dairy cattle; days open; genotypic factor; environmental factor.

Introduction

The primary goal of genetic selection in the dairy industry has been to develop cows with superior productive performance, characterized by high yields of milk, fat, and protein. The initiation of a new lactation is dependent on parturition, and the frequency of calving directly influences both herd profitability and biological efficiency.

During the past five decades, reproductive performance of dairy cows worldwide has shown a marked decline. Intense selection for increased milk yield has been associated with reduced reproductive efficiency, largely as a result of the unfavorable genetic correlation between milk production and fertility. Low fertility has negative consequences for both production and reproduction, including increased culling rates, higher costs of infertility management, a greater number of inseminations required per conception, and extended calving intervals (Zhu et al., 2024).

The calving-to-conception interval (CCI), also referred to as days open, represents the period between parturition and subsequent conception in dairy cows. This trait is of considerable economic importance and is frequently used as a criterion in genetic selection programs due to the ease and accuracy of its recording (Fathoni et al., 2024). The CCI shows the strongest functional association with the fertilizing capacity of cows. Jeong & Kim (2022) reported that Holstein cows requiring re-insemination for conception had a significantly longer CCI ($P < 0.001$) compared with those that conceived after the first insemination – 198.2 and 108.0 d, respectively. Similarly, Sasaki et al. (2020) demonstrated a curvilinear relationship ($R^2 = 0.997$–0.999) between the CCI and the number of services per conception.

The CCI serves as a key indicator of reproductive efficiency and is directly associated with the reproductive health status of dairy cows. Keshipour et al. (2024) reported that dystocia, as well as several reproductive tract disorders, including retained placenta and uterine prolapse, exerted a significant negative effect on the CCI ($P < 0.05$). Moreover, early postpartum health disorders occurring within two weeks after calving were found to extend the CCI by 7 to 15 d, depending on the nature of the disorder, with the most pronounced effect observed for inflammatory conditions (Macmillan et al., 2021). Similarly, Kitade et al. (2022) demonstrated that mastitis, endometritis, and follicular cysts, along with infections caused by *Staphylococcus aureus* and *Streptococcus* spp., significantly prolonged the CCI ($P < 0.05$). Stillbirths were also reported to extend the interval between calving and subsequent insemination by an average of 32 d compared with normal calvings (Constantin & Mihaela, 2023). In Friesian cows in Egypt, stillbirths and abortions prolonged the CCI by 71 and 28 days, respectively, relative to cows that calved normally (Ali & Sanad, 2021).

The calving-to-conception interval of dairy cows is also influenced by genetic factors. Fathoni et al. (2024) identified 16 single nucleotide polymorphisms (SNPs) located on 13 chromosomes that were significantly associated ($P < 0.001$–0.01) with the CCI of Thai × Holstein crossbred cattle. In Holstein cows, Tourchi et al. (2024) used the Bayes-GWAS approach to identify 10 SNPs located on BTA3, BTA7, and BTA17 that were also associated with CCI. In addition, Zamorano-Algandar et al. (2021) reported three SNPs in the *AVPR1A* (BTA5), *PRLR* (BTA20), and *SSTR2* (BTA19) genes that were significantly associated with the CCI ($P < 0.05$).

The CCI can serve as a predictor of the productive lifespan of dairy cows, which is of considerable importance to herd management and profitability. Reisi-Vanani et al. (2025) observed that Holstein cows with higher insemination indices and longer CCI exhibited shorter productive longevity. Similarly, Hu et al. (2023) reported that most reproductive traits of Holstein cows were negatively correlated with productive life, suggesting their potential use as indirect indicators of longevity. In contrast, Fahim et al. (2021) found no significant difference ($P > 0.05$) in the CCI between cows that were culled and those that remained in the herd (160.0 vs. 162.0 d).

Body condition before and/or during insemination also plays a crucial role in determining the CCI. Chuck et al. (2024) found that, in pasture-based dairy herds in Victoria (Australia), each additional unit of body condition score (BCS) at calving was associated with a 6.3-d reduction in the CCI. Likewise, Saranjam et al. (2020) demonstrated that substantial BCS loss after calving or low BCS at insemination prolonged the CCI in Iranian Holstein cows. Consistent with these findings, Jagusiak et al. (2023) suggested that incorporating BCS information into breeding programs could improve fertility, as cows in better physical condition tended to have shorter CCI.

The use of sex-sorted semen has been shown to influence reproductive performance. Zargaran et al. (2021) reported that cows inseminated with sex-sorted semen had a significantly ($P < 0.01$) longer CCI compared with those inseminated with conventional semen (158.5 vs. 136.1 d).

Variation in the CCI is largely attributable to environmental factors, as reflected by the generally low heritability estimates for fertility traits in dairy cattle (Arens et al., 2023). Reported heritability estimates for the CCI include 0.017 ± 0.005 for Holstein cows in China (Zhu et al., 2024), 0.04 in Iran (Tourchi et al., 2024), and 0.03 ± 0.01 in Egypt (Habib et al., 2024). Higher estimates have also been reported, including 0.12 (Easa et al., 2024) and 0.17 ± 0.04 (Chafai et al., 2024). The repeatability estimate for Moroccan Holstein cows was nearly identical (0.14 ± 0.02; Chafai et al., 2024).

Recce et al. (2021) found that primiparous Holstein cows that calved at an older age had a significantly ($P < 0.001$) longer CCI. Moreover, cows that gave birth to male calves had a longer CCI than those calving female offspring (157.0 vs. 149.0 d).

Taken together, these findings indicate that both genetic and environmental factors contribute substantially to variation in the calving-to-conception interval. Therefore, the objective of the present study was to analyze the effects of genotypic (sire) and environmental (parity, year, and season of calving) factors on the CCI variability, and to assess its relationship with milk productivity in Holstein cows.

Materials and methods

All experimental procedures involving animals were conducted in accordance with the 'Procedure for Conducting Experiments on Animals by Scientific Institutions' (Order of the Ministry of Education and Science, Youth and Sports of Ukraine No. 249, March 1, 2012), the Law of Ukraine 'On Protection of Animals from Cruelty' (No. 3447-IV, February 21, 2006), and the 'European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes' (Strasbourg, 1986). The experimental protocol was reviewed and approved by the Ethics Committee of Mykolayiv National Agrarian University (approval no. 2014/2). The study was conducted in compliance with the ARRIVE guidelines.

Information on the productivity and reproductive performance of Holstein cows that calved at PJSC 'Plemzavod Stepnoy' (Zaporizhzhia region, Ukraine) between 2014 and 2017 was included in the dataset. The experimental group comprised 238 cows impregnated by 14 breeding bulls. More detailed information on the pedigree composition of the experimental animals is provided in Kramarenko et al. (2025).

For each cow, the following traits of milk production were used: 305-d milk yield and milk fat percentage per lactation. In addition, the calving-to-conception interval was determined for each individual.

The effects of genotypic and environmental factors on the CCI were analyzed, including sire (14 subgroups), parity (three subgroups: first, second, and ≥ third lactations), year of calving (four subgroups: 2014, 2015, 2016, and 2017), and season of calving (four subgroups: winter, December–February; spring, March–May; summer, June–August; autumn, September–November).

Least squares means (LSM) for CCI were estimated using the General Linear Model (GLM) procedure (Al-Murrani, 2024) according to the following model:

$$Y_{ijklm} = \mu + Sire_i + Parity_j + YoC_k + SoC_l + e_{ijklm}, \quad (1)$$

where Y_{ijklm} – is the observed value; μ – is the overall means; $Sire_i$ – is the fixed effect of the i^{th} sires (i = 1–14); $Parity_j$ – is the fixed effect of the j^{th} parity (j = 1–3); YoC_k – is the fixed effect of the kth year of calving (k = 1–4); SoC_l – is the fixed effect of the lth season of calving (l = 1–4); ε_{ijklm} – is random error.

Differences among subgroup means were tested using Tukey's honestly significant difference (HSD) test, which is appropriate for unequal sample sizes.

The effects of parity and the CCI on 305-d milk yield and milk fat percentage were evaluated using a two-way ANOVA (fixed-effects model). According to the CCI, cows were classified into three groups: ≤90 d, 91–120 d, and ≥121 d.

All statistical analyses were performed using the Statistica software package (version 7.0; StatSoft Inc., Tulsa, OK, USA, 2004) following standard statistical procedures (Sokal & Rohlf, 1995) and Jamovi (version 2.6.19; Navarro & Foxcroft, 2025).

Results

The calving-to-conception interval of Holstein cows at PJSC 'Plemzavod Stepnoy' (Zaporizhzhia region, Ukraine) ranged from 49 to 557 d, with a mean of 123.2 ± 3.5 d (mean ± SE). The distribution of the CCI values departed significantly from normality (Shapiro–Wilk test: $W = 0.811$; $P < 0.001$) due to a pronounced right-hand tail. More than half of the observations (256 of 463; 55.9%) were within the range of 80 to 140 d, while the median (98.0 d) was markedly lower than the mean.

Least squares means (LSM ± SE) for the CCI by genotypic and environmental factors are summarized in Table 1. The results indicated that the bull sires used at PJSC 'Plemzavod Stepnoy' had no significant effect on the CCI of the daughters ($F = 1.59$; $P > 0.05$).

Table 1
Least squares means (LSM ± SE) for CCI duration by genotypic and environmental factors, d (n = 238)

Factors	*n*	*LSM* ± *SE*	95 % *CI* low	95 % *CI* high
Bull-sires:				
F (*P*)	–	1.59 (ns)	–	–
Parity:				
F (*P*)		7.49 (*P* < 0.001)		
1st	234	97.6 ± 6.5[a]	84.7	110.4
2nd	164	136.0 ± 7.9[b]	120.4	151.6
3rd and older	61	130.3 ± 13.4[ab]	103.8	156.7
Year of calving:				
F (*P*)		7.08 (*P* < 0.001)		
2014	63	155.2 ± 15.6[b]	124.7	185.8
2015	165	128.4 ± 9.1[b]	110.5	146.2
2016	197	133.2 ± 5.6[b]	122.2	144.1
2017	34	68.3 ± 13.8[a]	41.2	95.5
Season of calving:				
F (*P*)		3.68 (*P* = 0.012)		
winter	85	136.7 ± 9.5[b]	118.0	155.3
spring	125	132.3 ± 8.8[b]	115.0	149.7
summer	166	110.9 ± 7.9[a]	95.3	126.4
autumn	83	105.2 ± 9.8[a]	85.9	124.6

Notes: n – number of records; LSM ± SE – least squares mean estimate and its statistical error; F(P) – Fisher's criterion estimate and its significance level (based on GLM results); ns – $P > 0.05$; 95% CI Low, 95% CI High – the upper and lower limits of the 95% confidence interval of the corresponding LSM-estimate; significant differences between the means of individual subgroups ($P < 0.05$), as determined by the Tukey's HSD test, are indicated by different letters.

Parity had a significant effect on the calving-to-conception interval ($F = 7.49$; $P < 0.001$). The LSM-estimate of the CCI for primiparous cows (97.6 d) was significantly lower than that for cows in the second (136.0 d) or later lactations (130.3 d; Table 1). The year of calving also significantly influenced the CCI ($F = 7.08$; $P < 0.001$). The lowest LSM-estimate was observed in cows that calved in 2017 (68.3 d), whereas the highest was recorded in 2014 (155.2 d; see Table 1). Overall, there was a clear downward trend in the CCI of cows at PJSC 'Plemzavod Stepnoy' over the study period. The season of calving was likewise significantly associated with the CCI ($F = 3.68$; $P = 0.012$). Cows calving in summer or autumn had shorter intervals (105.2–110.9 d) than those calving in winter or spring (132.3–136.7 d; Table 1).

Results of the two-way ANOVA (fixed-effects model) assessing the effects of parity and the CCI on 305-d milk yield indicated a significant influence of both parity ($F = 38.82$; $P < 0.001$) and their interaction ($F = 2.95$; $P = 0.020$). The highest milk yield (11,840.7 kg) was observed in multiparous cows (third and later lactations) with the CCI of 91–120 d (Fig. 1a).

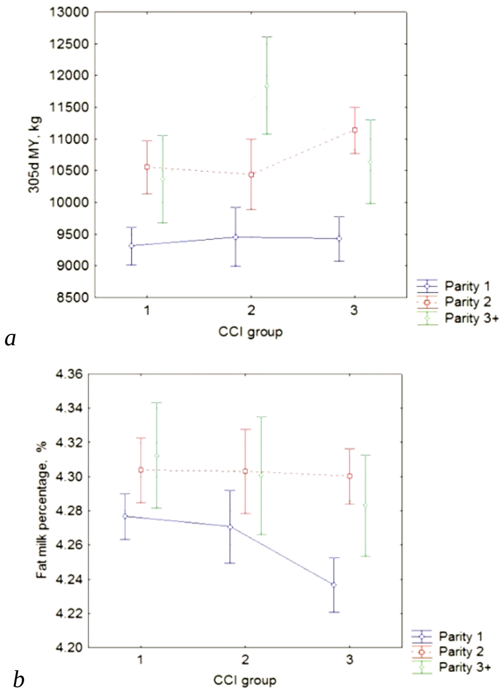

Fig. 1. The effect of parity and the CCI class on the 305-d milk yield (*a*) and fat milk percentage (*b*) in Holstein cows (n = 238): CCI group: *1* – ≤ 90 days; *2* – 91–120 days; *3* – ≥ 121 days; the corresponding estimates are provided with 95% confidence intervals

For milk fat percentage, both parity (F = 16.60; P < 0.001) and the CCI (F = 4.01; P = 0.023) had significant effects. Regardless of parity, there was a general trend of decreasing milk fat percentage with increasing CCI, most notably among primiparous cows (Fig. 1b).

Discussion

Previous research by Sahwan et al. (2021) reported that the largest proportion of Holstein cows in Egypt (approximately 40%) had a calving-to-conception interval between 61 and 140 d, although about one-third of inseminations occurred between 200 and 400 d of lactation. The CCI is known to exhibit substantial individual and interherd variation. The shortest recorded CCI value was 10 d for Holstein cows in China (Zhu et al., 2024), whereas the longest was 683 d for cows in Morocco (Chafai et al., 2024).

Remmik et al. (2020) found that the mean CCI across 14 Estonian farms with Holstein cows ranged from 101.0 to 151.0 d. On 9 Iranian farms, the corresponding range was 128.8 to 142.1 d (Mahnani et al., 2021). Moreover, average farm size was associated with the CCI performance. In Turkey, Öztürk & Sipahi (2021) reported that farms with ≤ 10 Holstein cows had an average CCI of 186.0 ± 7.9 d, whereas farms with 11–50 cows showed a significantly shorter interval (131.1 ± 5.7 d).

Table 2 summarizes the LSM-estimates of CCI in dairy cattle breeds of European and American origin by country. Analysis of these data reveals several consistent patterns. First, average CCI values for most major dairy breeds worldwide were 1.5–2.0 times greater than the standard reference range of 85–90 d.

Table 2
Least squares means (LSM ± SE) for the CCI depending on the breed of dairy cattle of European/American origin and the country of breeding (d)

Breed	Country	n	LSM ± SD (min-max)	Source
Friesian	Egypt	9,155	159.0 ± 77.8	Zahed et al. (2020)
Holstein	Argentina	639	160.0 ± 159.3 (18–673)	Beribe et al. (2024)
-“-	Brazil	1,902	154.6 ± 40.5	Lourenço et al. (2022)
-“-	-“-	9,421	158.4 ± 87.0 (20–365)	Dominguez-Castaño et al. (2020)
-“-	-“-	3,926	154.4 ± 77.6 (35–365)	Almeida et al. (2021)
-“-	Honduras	3,235	168.3 ± 104.7	Estrada-León et al. (2024)
-“-	-“-	254	153.4 ± 89.2 (41–560)	Cañizares-Martínez et al. (2021)
-“-	Greece	2,000	132.7 ± 254.9	Hajibemani & Mirzaei (2022)
-“-	Estonia	4,474	125.6	Remmik et al. (2020)
-“-	Egypt	2,040	184.0 ± 88.0 (20–400)	Elmaghraby et al. (2025)
-“-	-“-	2,538	166.5 ± 120.9	Habib et al. (2024)
-“-	-“-	920	164.3 ± 79.8	Kilany et al. (2023)
-“-	-“-	875	136.8 ± 44.1	El-Bakly et al. (2023)
-“-	-“-	1,717	173.2 ± 114.1	El-Sherief et al. (2022)
-“-	-“-	10,994	161.0 ± 104.9	Fahim et al. (2021)
-“-	-“-	18,221	159.7 ± 124.9	Moawed et al. (2021)
-“-	-“-	1,096	190.0 ± 198.6	Sadek et al. (2021)
-“-	Iran	340	131.1 ± 52.3	Keshipour et al. (2024)
-“-	-“-	78,517	109.0 ± 53.0	Barzehkar et al. (2023)
-“-	-“-	116,110	135.5 ± 67.3	Mahnani et al. (2021)
-“-	Canada	726,259	118.0*	Alemu et al. (2023)
-“-	China	26,766	156.8 ± 100.2 (10–560)	Zhu et al. (2024)
-“-	-“-	90,466	123.5 ± 71.1 (22–1470)	Hu et al. (2023)
-“-	-“-	3,771	105.1 ± 57.2 (27–396)	Nan et al. (2023)
-“-	Morocco	7,600	156.9 ± 54.6 (24–683)	Chafai et al. (2024)
-“-	-“-	5,680	125.0 ± 61.3 (30– 330)	Boujenane & Draga (2021)
-“-	Mexico	415,859	131.6 ± 74.0	Durán-Alvarez et al. (2023)
-“-	-“-	504	103.2 ± 36.4 (60–198)	Zamorano-Algandar et al. (2021)
-“-	South Africa	24,909	137.0 ± 72.0 (21–435)	Kgari et al. (2023)
-“-	Poland	35,882	133.0 ± 66.0	Ghiasi et al. (2021)
-“-	Portugal	766,897	120.8 ± 53.6 (42–252)	Silva et al. (2020)
-“-	Republic of Korea	33,100	130.7 ± 42.1	Lee et al. (2024)
-“-	USA	37,680	114.0 ± 48.0 (42–325)	Overton & Eicker (2025)
-“-	Turkey	2,005	154.3 ± 111.9	Öztürk & Sipahi (2021)
-“-	Ukraine	463	123.2 ± 75.8 (49–557)	our data
-“-	Japan	814	134.0*	Kitade et al. (2022)
Holstein-Friesian	Egypt	1,017	182.0 ± 124.0	El-Komy & Rashad (2021)
Jersey	Ethiopia	1,164	186.9 ± 238.8	Didanna & Asmirew (2025)
Montbeliarde × Holstein crossbred	Egypt	412	124.1 ± 35.5	El-Bakly et al. (2023)
-“-	-“-	1,172	132.0 ± 178.0	Sadek et al. (2021)
Thai × Holstein crossbred cattle	Thailand	59,415	97.0 ± 28.5 (35–150)	Fathoni et al. (2024)

Notes: min, max – minimum and maximum values; SD – standard deviation; * – median estimate.

The closest to the standard was observed in Thai × Holstein crossbred cows (97.0 d) (Fathoni et al., 2024), whereas a single herd of Holsteins in Egypt exhibited a markedly longer CCI of 190.0 d (Sadek et al., 2021).

Second, substantial within-country variation in the CCI was evident even under similar climatic conditions. Among studies conducted on Holstein cows in Egypt, LSM-estimates ranged from 138.8 d (El-Bakly et al., 2023) to 190.0 d (Sadek et al., 2021). Comparable variation was observed in China, where estimates ranged from 105.1 d (Nan et al., 2023) to 156.8 d (Zhu et al., 2024).

Third, crossbred cows generally showed shorter CCI values than purebred Holsteins. El-Bakly et al. (2023) demonstrated that purebred Holstein cows had significantly longer CCIs than Montbéliarde × Holstein crossbreds (P < 0.01). Under subtropical conditions in Egypt, Nasr et al. (2021) also observed that purebred Holstein cows (147.9 d) had longer intervals (P < 0.001) than Holstein × Fleckvieh crossbreds (116.7 d), but did not differ from Holstein × Brown Swiss crossbreds (134.3 d). In Thailand, Fathoni et al. (2024) reported that animals with the lowest proportion of Holstein ancestry (≤ 87.5 %) had significantly shorter CCIs.

El-Komy & Rashad (2021) reported a significant effect (P < 0.01) of sire on milk production traits in Holstein-Friesian cows in Egypt, but no effect on reproductive traits, including the CCI. Conversely, Barzehkar et al. (2023) found a negative correlation between the CCI of Holstein cows and the predicted breeding value of their sires, suggesting that the CCI may influence sire evaluations and breeding value prediction.

The present findings are consistent with previous reports. Among 23 studies published between 2020 and 2025 that examined the effect of lactation number on the CCI in dairy cattle of European and American origin, 16 reported a significant effect (Table 3). Thus, the probability that this pattern occurred by chance was low (Binomial test, P = 0.047). The significance of this relationship was not associated with sample size (Mann–Whitney U test: Z = −0.67; P = 0.504).

Table 3
The results of the influence of cow age (in lactations) on the CCI, depending on the breed of dairy cattle of European/American origin and the country of breeding

Breed	Country	*n*	P_{Parity}	Lactations order	Source
Holstein	Argentina	10,555	< 0.001	1>2+	Recce et al. (2021)
-“-	Brazil	3,410	ns	–	Vieira et al. (2022)
-“-	-“-	3,926	< 0.001	1<2<3+	Almeida et al. (2021)
-“-	Egypt	10,034	< 0.001	1>2=3=4=5+	Easa et al. (2024)
-“-	-“-	1,717	< 0.001	1>2+	El-Sherief et al. (2022)
-“-	-“-	10,994	< 0.001	1>2<3>4=5+	Fahim et al. (2021)
-“-	-“-	2,040	ns	–	Sahwan et al. (2021)
-“-	Iran	200,644	< 0.05	1>2<3=4=5<6	Zahedi et al. (2021)
-“-	Spain	199	< 0.05	1=2=3<4=5+	Yáñez et al. (2024)
-“-	Canada	726,259	< 0.001	1<2<3<4+	Alemu et al. (2023)
-“-	China	3,771	ns	–	Nan et al. (2023)
-“-	Morocco	4,186	< 0.01	1<2=3	Chafai et al. (2024)
-“-	-“-	5,680	ns	–	Boujenane & Draga (2021)
-“-	Republic of Korea	33,100	< 0.001	1<2<3	Lee et al. (2024)
-“-	Turkey	2,005	ns	–	Öztürk & Sipahi (2021)
-“-	Ukraine	463	< 0.001	1<2+	our data
-“-	Sweden	481,157	< 0.05	1>2	Liedgren et al. (2024)
-“-	Japan	814	< 0.005	1<2=3+	Kitade et al. (2022)
Holstein, Montbeliarde × Holstein crossbred	Egypt	2,268	ns	–	Sadek et al. (2021)
Holstein-Friesian	–	1,017	< 0.05	1=2>3<4=5	El-Komy & Rashad (2021)
Jersey	Sweden	6,024	ns	–	Liedgren et al. (2024)
-“-	Ethiopia	1,164	0.029	1=2=3=4>5+	Didanna & Asmirew (2025)
Thai × Holstein crossbred cattle	Thailand	59,415	< 0.05	1=2 >3=4=5	Fathoni et al. (2024)

Note: P_{Parity} – the level of significance of the influence of the number of lactations (based on GLM results); lactation order – the presence of significant differences in LSM-estimates for different lactations; the symbols ‘<’ and ‘>’ indicate significant differences between adjacent lactations, while ‘=’ indicates no significant differences.

A common observation among these studies was an increase in the CCI with advancing lactation number, particularly between the first and third lactations (Almeida et al., 2021; Kitade et al., 2022; Alemu et al., 2023). Similar results were obtained in our experimental group. However, several studies reported the opposite trend, with longer CCIs in primiparous than in multiparous cows (Recce et al., 2021; El-Sherief et al., 2022; Easa et al., 2024). Didanna & Asmirew (2025) reported that in Jersey cattle in Ethiopia, the CCI decreased progressively from the first to the fifth or sixth lactation, likely due to improved reproductive organ condition in older cows, faster uterine involution, and earlier resumption of ovarian activity after calving.

High year-to-year variation in productive and reproductive traits may result from changes in herd size, age structure, and management practices, as well as from corresponding phenotypic trends (El-Komy & Rashad, 2021). Among 11 studies from 2020–2025 that analyzed the effect year of calving on the CCI, 10 detected significant effects (Table 4; Binomial test, P = 0.006). Similarly, of 20 studies evaluating the effect season of calving, 15 found significant differences (Table 4; Binomial test, P = 0.021).

Analysis of seasonal patterns revealed that the longest CCI values were typically observed in cows calving during spring or summer, whereas the shortest intervals occurred in autumn or winter. Because insemination typically begins 2–3 months after calving, the highest CCI values correspond to cows inseminated in summer or early autumn – periods of high ambient temperature. In Egypt, Holstein cows inseminated in summer were 2.18 times more likely to require reinsemination (P < 0.01), leading to longer CCIs than cows inseminated during winter (Elmaghraby et al., 2025).

Kilany et al. (2023) demonstrated that an increase in temperature-humidity index (THI) significantly increased the CCI (P < 0.001). This effect is likely due to heat stress impairing estrus expression and conception rates, resulting in prolonged intervals (El-Bakly et al., 2023). Recce et al. (2021) similarly reported that elevated THI values (≥ 72) reduced reproductive performance in Holstein cows in Argentina, with carryover effects on the fertility of their daughters. Nan et al. (2023) further observed an interaction between cow age and calving season, suggesting that the microenvironment created by seasonal factors may play a decisive role in insemination success.

Abd-El Hamed & Kamel (2021) found that Holstein-Friesian cows achieved the highest milk yield when the CCI ranged from 91 to 110 d. In the present study, primiparous cows produced significantly less milk than multiparous cows regardless of the CCI, consistent with earlier findings in native Ukrainian breeds (Kramarenko et al., 2022; Gritsienko et al., 2024) and imported dairy breeds (Polishchuk et al., 2021).

A clear relationship has been reported between milk yield in the preceding lactation and subsequent the CCI. In Hungarian dairy cattle, an increase of 2,000 kg in milk yield per lactation was associated with a 9% increase in the CCI and a 13% rise in insemination index (Amma et al., 2024). Similarly, Recce et al. (2021) found that high milk production during the first lactation in Argentine Holsteins led to significantly longer subsequent CCIs (P < 0.001).

Table 4
The results of the influence of the year and season of calving on the CCI, depending on the breed of dairy cattle of European/American origin and the country of breeding

Breed	Country	*n*	$n_{Y/P}$	P_{YoC}	P_{SoC}	Seasons order	Source
Holstein	Argentina	10,555	na	na	< 0.001	(spr+sum) > (aut+win)	Recce et al. (2021)
-"-	Brazil	3,926	na	na	< 0.001	spr > win = sum > aut	Almeida et al. (2021)
-"-	Egypt	2,040	1/1	na	< 0.05	sum > win	Elmaghraby et al. (2025)
-"-	-"-	10,034	23/4	< 0.001	< 0.001	(win+spr) > (sum+aut)	Easa et al. (2024)
-"-	-"-	1,717	11/1	na	0.018	sum > win	El-Sherief et al. (2022)
-"-	-"-	10,994	12/3	< 0.001	< 0.001	spr > win = sum > aut	Fahim et al. (2021)
-"-	Iran	200,644	12/1	< 0.05	< 0.05	sum > spr = win > aut	Zahedi et al. (2021)
-"-	Spain	199	1/1	na	ns	–	Yáñez et al. (2024)
-"-	Canada	726,259	3/1	< 0.001	< 0.01	spr > aut > sum	Alemu et al. (2023)
-"-	China	3,771	na	na	< 0.05	spr > sum = win > aut	Nan et al. (2023)
-"-	Morocco	5,680	2/1	na	< 0.001	spr > win = sum = aut	Boujenane & Draga (2021)
-"-	Turkey	2,005	7/1	< 0.001	ns	–	Öztürk & Sipahi (2021)
-"-	Ukraine	463	4/1	< 0.001	0.012	(win + spr) > (sum + aut)	our data
-"-	Japan	160	13/4	ns	ns	–	Kusaka et al. (2022)
-"-	-"-	814	2/1	na	ns	–	Kitade et al. (2022)
Holstein, Montbeliarde × Holstein crossbred	Egypt	2,268	9/1	< 0.05	< 0.05	spr > win = sum > aut	Sadek et al. (2021)
Holstein, Jersey, Holstein × Jersey crossbred	Argentina	890	na	na	ns	–	Beribe et al. (2024)
Holstein, Montbeliarde × Holstein crossbred	Egypt	1,077	4/1	< 0.05	< 0.01	win < sum	El-Bakly et al. (2023)
Holstein-Friesian	-"-	1,017	7/1	< 0.01	< 0.01	spr > win = sum > aut	El-Komy & Rashad (2021)
Jersey	Ethiopia	1,164	16/5	0.005	0.003	rainy > dry	Didanna & Asmirew (2025)

Notes: $n_{Y/P}$ – number of years and periods of study; P_{YoC} – level of significance of the influence of the year/period of calving (according to GLM results); P_{SoC} – level of significance of the influence of the season of calving (according to GLM results); na – no data available; the symbol '>' indicates that significant differences have been established between the corresponding calving seasons; the calving seasons are winter (win), spring (spr), summer (sum) and autumn (aut). 'rainy' and 'dry' refer to the wet and dry seasons of the year.

In Canada, Alemu et al. (2023) reported that cows with medium or high yields in the previous lactation had significantly lower insemination indices (P ≤ 0.001–0.004) but longer CCIs. Sahwan et al. (2021) also observed that Holstein cows with low 305-d milk yields experienced shorter subsequent CCIs than higher-producing cows.

Collectively, these findings demonstrate a close and multifactorial relationship between milk production and the calving-to-conception interval. The CCI is influenced by both genetic and environmental factors, and selection focusing solely on milk yield can adversely affect fertility. Long-term herd productivity can be improved by incorporating reproductive traits into breeding programs and accounting for environmental influences (Estrada-León et al., 2024).

Conclusion

Under the conditions of PJSC 'Plemzavod Stepnoy' (Zaporizhzhia region, Ukraine), the mean calving-to-conception interval of Holstein cows was 123.2 ± 3.5 da, ranging from 43 to 557 da. The sires used in the herd had no significant effect on the calving-to-conception interval of their daughters. Primiparous cows had significantly shorter LSM-estimates for the calving-to-conception interval (97.6 d) compared with multiparous cows (130.3–136.0 d; P < 0.05). A general downward trend in the calving-to-conception interval was observed over the study period, with the lowest LSM-estimates (68.3 d) recorded in cows calving in 2017. The season of calving had a significant effect on the calving-to-conception interval (F = 3.68; P = 0.012). Cows calving in summer or autumn exhibited shorter the calving-to-conception interval (105.2–110.9 d) than those calving in winter or spring (132.3–136.7 d). A significant interaction between parity and days open on 305-d milk yield was detected (F = 2.95; P = 0.020). Multiparous cows (third or later lactations) with 91–120 d open achieved the highest milk yield (11,840.7 kg), whereas primiparous cows consistently produced less milk regardless of their calving-to-conception interval. Additionally, milk fat percentage tended to decrease with increasing days open, particularly among primiparous cows.

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