Rocz. Nauk. Zoot., T. 52, z. 2 (2025): 269–277 *DOI: 10.58146/02xk-g797*

RELATIONSHIP BETWEEN MILK YIELD AND FERTILITY TRAITS IN POLISH HOLSTEIN-FRIESIAN COWS IN THE MAŁOPOLSKA REGION

Agnieszka Otwinowska-Mindur[1], Andrzej Żarnecki[2]

[1]University of Agriculture in Krakow, Faculty of Animal Science, Department of Genetics, Animal Breeding and Ethology, al. Mickiewicza 24/28, 30-059 Krakow, Poland
[2]National Research Institute of Animal Production, Department of Cattle Breeding, 32-083 Balice near Krakow, Poland

E-mail: agnieszka.otwinowska@urk.edu.pl

ORCID
Agnieszka Otwinowska-Mindur: 0000-0002-4518-0821
Andrzej Żarnecki: 0000-0003-4036-9665

Funding source: This study was carried out with financial support from the Ministry of Science and Higher Education (funds for statutory activities, SUB.215-D201).

Abstract

The aim of the study was to analyze selected fertility measures in Polish Holstein-Friesian cows kept on farms in the Małopolska region at different levels of 305-day milk yield. The data concerned 5,980 cows from 167 herds. The calving-to-first-insemination interval (CFI), days open (DO), and calving interval (CI) were analyzed. According to 305-day milk yield, cows were divided into four yield classes: 1) up to 8,000 kg, 2) 8,001–10,000 kg, 3) 10,001–12,000 kg, and 4) over 12,000 kg. The effects of lactation number and milk-yield class on CFI, DO, and CI were examined using the nonparametric Kruskal-Wallis test. CFI differed highly significantly between the first and third calving ($P \leq 0.01$). In addition, a highly significant association ($P \leq 0.01$) was found between 305-day milk-yield class and the length of CFI, DO, and CI. Increasing 305-day milk yield was accompanied by longer DO and CI and a shorter CFI, which may indicate reduced reproductive efficiency in cows.

Keywords: Holstein-Friesian cattle, milk yield, fertility traits

Introduction

Until the beginning of the 21st century, genetic selection programs for dairy cattle in most countries focused mainly on milk production, often at the expense of functional traits such as fertility, calving-related traits, herd life, and milking speed. At the beginning of this century, improvement of dairy cattle populations was redirected toward a more balanced breeding objective in which functional traits began to play an increasingly important role. At the same time, an adverse consequence of many years of selection of dairy cattle mainly for increased milk yield has been the increasingly frequent occurrence of reproductive disorders. Despite the widespread use of estrous-cycle control, ovulation induction, and timed insemination, fertility has continued to deteriorate (Crowe et al., 2018). Because female fertility is one of the main factors

affecting the profitability of milk production, declining fertility is associated with economic losses (Jaśkowski et al., 2006; Bogucki et al., 2007).

Interval fertility measures, such as the calving-to-first-insemination interval, days open, and calving interval, are commonly used in breeding, among other reasons because the data needed to calculate them are readily available: dates of calving, conception, and insemination are recorded in national breeding programs. At the same time, fertility measures have low heritability, so their variability is substantially affected by environmental factors, including nutrition, age at first calving, calving number, and body condition (Bogucki et al., 2007; Crowe et al., 2018; Nowak et al., 2024).

High milk yield is associated with high energy requirements, which may lead to metabolic and hormonal disturbances affecting cow fertility. Negative energy balance, feeding errors, physiological stress, changes in hormone levels, long calving intervals, and impaired body condition are among the main factors that may reduce the reproductive capacity of dairy cows (Lucy, 2001; Jaśkowski et al., 2006; Crowe et al., 2018). As milk yield increases, calving interval, days open, reproductive rest, and service period become longer, while the insemination index increases (Januś and Borkowska, 2006; Bogucki et al., 2007; Sawa and Bogucki, 2011; Djedović et al., 2012). Increasing milk yield is also associated with a higher incidence of metabolic diseases such as ketosis and acidosis, more frequent reproductive problems, and consequently a shorter productive life (Januś and Borkowska, 2006; Bogucki et al., 2007).

The aim of the study was to analyze the calving-to-first-insemination interval, days open, and calving interval in black-and-white Polish Holstein-Friesian cows kept on farms in the Małopolska region at different levels of 305-day milk yield.

Material and methods

The data used in the study came from the FedInfo database, were provided by the Polish Federation of Cattle Breeders and Dairy Farmers, and concerned 5,980 Polish Holstein-Friesian cows from 167 herds. The cows were born between 2010 and 2020 and calved between 2011 and 2022. The dataset included 3,658 cows calving for the first time, 1,663 cows calving for the second time, and 659 cows calving for the third time.

The following traits were analyzed:

1. Calving-to-first-insemination interval (CFI), i.e. the number of days between calving and the first subsequent insemination.
2. Days open (DO), i.e. the number of days from calving to the next conception (calving-to-conception interval).
3. Calving interval (CI), i.e. the number of days between successive calvings.

CFI, DO, and CI were defined after the first, second, and third calving. According to 305-day milk yield, cows were divided into four milk-yield classes. The first group comprised cows producing up to 8,000 kg of milk; the second and third groups comprised cows producing 8,001–10,000 kg and 10,001–12,000 kg of milk, respectively. The fourth group included cows producing more than 12,000 kg of milk during 305 days of lactation. Complete lactations lasted from 280 to 1,101 days. The numbers of cows assigned to each milk-yield class in successive lactations are shown in Figure 1.

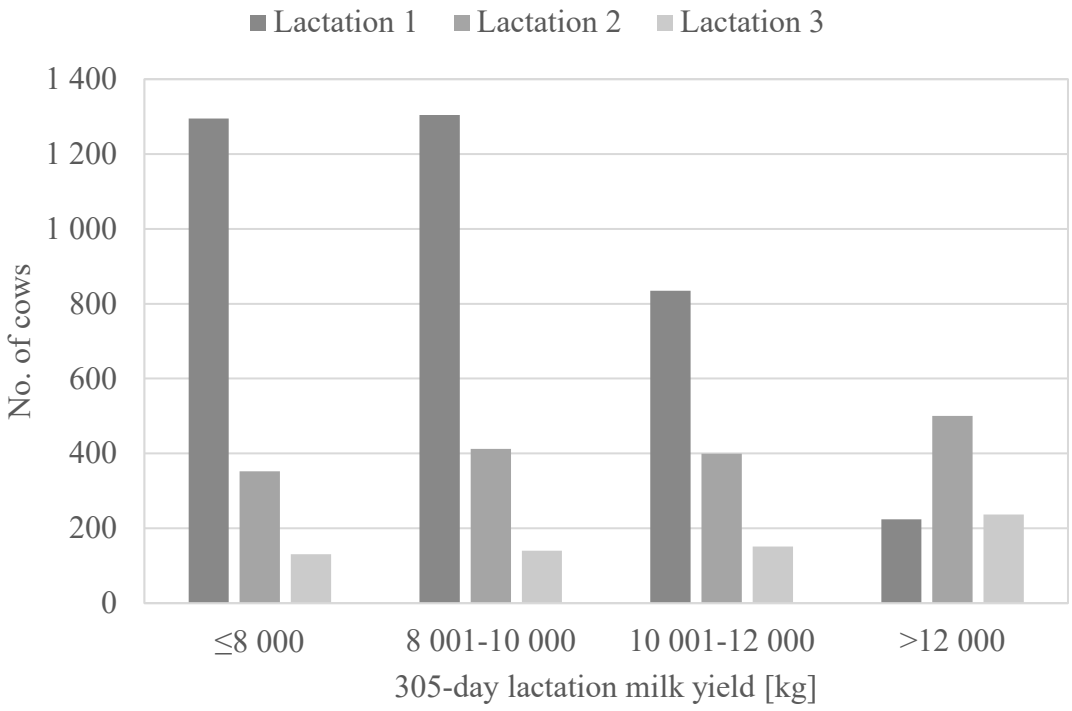


Figure 1. Number of cows by 305-day milk yield class and lactation number

The analysis was performed using a program written in Python (Van Rossum and Drake, 2009) and the NumPy (Harris et al., 2020), SciPy (Virtanen et al., 2020), Scikit-learn (Pedregosa et al., 2011), and Pandas (McKinney, 2010) libraries. Normality of the distributions of the analyzed traits (CFI, DO, and CI) was assessed using the Kolmogorov-Smirnov test, after which the significance of differences between mean fertility measures according to lactation number and milk-yield class was evaluated. Because the fertility measures were not normally distributed, the effects of calving number and milk-yield class on CFI, DO, and CI were examined using the nonparametric Kruskal-Wallis test. Dunn's test was used for multiple comparisons.

Results

Table 1 presents the characteristics of the calving-to-first-insemination interval, days open, and calving interval after the first, second, and third calving. Mean CFI decreased with successive calvings. CFI ranged from 20 to 617 days after the first calving, from 18 to 487 days after the second calving, and from 23 to 443 days after the third calving. In addition, mean CFI differed highly significantly between the first and third calving ($P \leq 0.01$). Mean DO was approximately 149 days after the first, second, and third calving and did not differ significantly ($P > 0.05$) between successive calvings. DO ranged from 31 to more than 1,020 days after the first calving and from 30 to approximately 640 days after subsequent calvings. Mean CI was approximately 428 days and did not differ significantly ($P > 0.05$) between successive calvings. CI ranged from 306 to 1,314 days after the first calving, from 306 to 922 days after the second calving, and from 324 to 853 days after the third calving in cows from Małopolska.

Table 1. Effect of calving number on female fertility traits

Calving no.	No. of cows	CFI1)		DO2)		CI3)	
		Mean	SD[4)]	Mean	SD[4)]	Mean	SD[4)]
I	3 658	89,75^{A}	49,74	150,79^{A}	91,21	430,01^{A}	91,97
II	1 663	86,56^{AB}	45,89	148,47^{A}	82,87	427,31^{A}	82,97
III	659	85,44^{B}	50,00	149,55^{A}	88,03	428,19^{A}	88,27
P[5)]		$4{,}19 \cdot 10^{-3}$		$9{,}06 \cdot 10^{-1}$		$9{,}06 \cdot 10^{-1}$	

1) CFI – calving-to-first-insemination interval [days]
2) DO – days open, i.e. calving-to-conception interval [days]
3) CI – calving interval [days]
4) SD – standard deviation
5) P – p-value
A, B – means in columns marked with different letters differ highly significantly (P≤0.01)

Increasing 305-day milk yield was accompanied by a shortening of the calving-to-first-insemination interval and lengthening of both days open and calving interval (Table 2). A highly significant association (P≤0.01) was found between lactation milk-yield class and the length of CFI, DO, and CI. Mean CFI was generally shorter in higher-yielding cows and ranged from approximately 100 days in cows producing less than 8,000 kg of milk to approximately 73 days in cows producing more than 12,000 kg. CFI differed highly significantly among the four defined milk-yield classes. Mean DO increased with increasing 305-day milk yield, from approximately 147 to 163 days. CI increased across successive lactation milk-yield classes from 424 days in cows producing 10,001–12,000 kg of milk to 440 days in cows producing more than 12,000 kg. In addition, mean DO and CI in cows producing more than 12,000 kg of milk differed significantly from DO and CI in cows producing less than 12,000 kg.

Table 2. Effect of 305-day milk yield on female fertility traits

Milk yield [kg]	No. of cows	CFI1)		DO2)		CI3)	
		Mean	SD[4)]	Mean	SD[4)]	Mean	SD[4)]
≤8000	1778	99,37^{A}	54,24	146,90^{A}	90,78	427,67^{A}	91,35
8 001–10 000	1856	92,24^{B}	49,74	148,73^{A}	85,84	427,77^{A}	86,77
10 001–12 000	1385	79,52^{C}	41,99	146,75^{A}	85,20	424,55^{A}	85,68
>12 000	961	73,39^{D}	38,00	162,95^{B}	93,47	440,61^{B}	93,51
P[5)]		$1{,}43 \cdot 10^{-69}$		$4{,}93 \cdot 10^{-7}$		$1{,}85 \cdot 10^{-5}$	

1) CFI – calving-to-first-insemination interval [days]
2) DO – days open, i.e. calving-to-conception interval [days]
3) CI – calving interval [days]
4) SD – standard deviation
5) P – p-value
A, B, C, D – means in columns marked with different letters differ highly significantly (P≤0.01)

Discussion

The mean calving-to-first-insemination interval determined in the present study is consistent with results reported by other authors (Borkowska et al., 2012; Toledo-Alvarado et al., 2017; Otwinowska-Mindur et al., 2022). Borkowska et al. (2012) reported a CFI of 85 days after the

first calving and 90 days after the third and subsequent calvings. In the study by Toledo-Alvarado et al. (2017), the mean calving-to-first-insemination interval in Holstein cows was approximately 93 days. Otwinowska-Mindur et al. (2022), in turn, estimated the mean CFI at approximately 89 days, although that study included only cows after the first calving.

The mean DO (approximately 150 days) and CI (approximately 430 days) determined in the present study after the first, second, and third calving did not differ significantly (Table 1), indicating relative stability of these fertility measures across successive lactations. Borkowska et al. (2012) reported the shortest DO after the first calving, at 162 days, and the longest DO after the third and subsequent calvings, ranging from 176 to 181 days. Shorter DO values were reported by Toledo-Alvarado et al. (2017) and Otwinowska-Mindur et al. (2022), at 135 and 121 days, respectively. Borkowska et al. (2012) and Piwczyński et al. (2020) estimated mean CI values similar to those obtained in the present study. Borkowska et al. (2012) observed the shortest CI after the first calving, at 420 days, whereas after the second and subsequent calvings it exceeded 430 days. Piwczyński et al. (2020) showed that calving interval increased from 411–417 days after the first calving to 423–428 days after the second, depending on the cow housing system. Remmik et al. (2020), however, obtained a slightly shorter CI (402 days) than in the present study.

Lactation milk yield had a highly significant effect on all three analyzed fertility measures (CFI, DO, and CI). As milk yield increased, CFI became shorter, whereas DO and CI became longer (Table 2). These results, indicating an adverse effect of high milk yield on the analyzed fertility measures, are consistent with reports by other authors (Januś and Borkowska, 2006; Bogucki et al., 2007; Sawa and Bogucki, 2011; Borkowska et al., 2012; Djedović et al., 2012). Borkowska et al. (2012) showed that CFI increased with increasing milk yield. Mean CFI after the first calving was 83 days in cows producing less than 3,000 kg of milk during the first 100 days of lactation, compared with 97 days in cows producing more than 3,600 kg. According to Januś and Borkowska (2006), DO increased with milk yield from 111 to 146 days; their analysis used yield classes based on 305-day milk yield corrected to 4% fat. Bogucki et al. (2007) reported that DO increased with milk yield, from 98 days in cows producing less than 6,000 kg of milk to 264 days in cows producing more than 14,000 kg in a complete lactation. By contrast, in the study by Borkowska et al. (2012), DO decreased from 195 days in cows producing less than 3,000 kg of milk in the first 100 days of lactation to 188 days in cows producing more than 3,600 kg, indicating the opposite tendency.

In the study by Bogucki et al. (2007), calving interval increased from 369 days in cows producing less than 6,000 kg of milk in a complete lactation to 540 days in cows producing more than 14,000 kg. Sawa and Bogucki (2011), in turn, showed that in primiparous cows an increase in milk yield from below 5,000 kg to above 8,000 kg resulted in an increase in CI from 378 to 517 days. Borkowska et al. (2012) estimated CI values ranging from 419 days in cows producing less than 3,000 kg of milk during the first 100 days of lactation to 446 days in cows producing more than 3,600 kg.

A longer calving interval in high-yielding cows may allow fuller use of their production potential during lactation. Remmik et al. (2020) showed that a longer CI after the first calving was associated with higher lifetime milk yield and a lower risk of early culling. However, as emphasized by Bogucki et al. (2007), prolongation of lactation should result from a deliberate breeder decision rather than from reproductive disorders. Januś and Borkowska (2006) observed that increasing milk yield was accompanied by longer DO and CI, which may indicate reduced reproductive efficiency. Amma et al. (2024) found that each additional kilogram of milk increased DO by 0.0044%, meaning that an increase in milk yield of 2,000 kg translated into an approximately 9% increase in DO. Januś and Borkowska (2006) noted that reduced reproductive efficiency may result from difficulties in meeting the very high energy requirements of cows in early lactation. During this period, nutrients are directed to a greater extent

toward intensive milk production at the expense of processes associated with the resumption of cyclic ovarian activity and establishment of a new pregnancy. Djedović et al. (2012) and Amma et al. (2024) stated that the observed adverse phenotypic correlations between milk production and fertility measures indicate that long-term selection of cows solely for milk yield may negatively affect their reproductive capacity. Toledo-Alvarado et al. (2017) found that cow fertility depends to a considerable extent on milk yield. Piwczyński et al. (2020), however, showed that cows milked with automatic milking systems had higher 305-day milk yield and more favorable values of selected fertility measures than conventionally milked cows. The authors observed a positive trend suggesting that milk yield and fertility may be improved simultaneously, possibly as a result of improved cow welfare associated with robotic milking. At the same time, Amma et al. (2024) pointed out that deterioration of reproductive measures with increasing milk yield may have an environmental rather than genetic basis. These conclusions are supported by Nowak et al. (2024), who found that selected fertility measures, including DO, are significantly affected by environmental factors such as age at first calving and year of first calving.

In summary, the absence of significant differences in days open and calving interval among the first three calvings indicates stability of these fertility measures across successive lactations in Holstein-Friesian cows. This may suggest that under appropriate herd-management conditions, age and calving number do not substantially affect basic reproductive measures. In addition, increasing 305-day milk yield was accompanied by longer DO and CI and shorter CFI, which may indicate reduced reproductive efficiency. Long-term selection of cows exclusively for high milk yield may adversely affect their fertility and overall reproductive performance.

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Approved for publication: 25 September 2025

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SUMMARY

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