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Genetic determination of reproduction rate traits in dairy cattle breeding

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Abstract. The relevance of the study is due to the need to control economically important attributes of the reproduction of dairy cattle, which have a weak genetic determination and substantially depend on the management and feeding of cows. The purpose of the study is to determine the relationship between the duration of the voluntary waiting period, days open, and period of insemination, assess the impact of the father factor on them. An examination of the influence of genetic and environmental factors on the voluntary waiting period, days open, and milk productivity was conducted. A new feature is highlighted – the period of insemination, which was determined as the difference between the lengthening of the open day period and the voluntary waiting period. Studies were conducted on Holstein cows (a total of 605 heads), the average yield of which was 8777 kg. As a source of primary information, data from the Uniform Agri programme was used, which was processed using variance and correlation-regression analysis. The probable influence of the father factor on milk during 305 days of lactation (11.5%), days open (5.4%), and the period of insemination (5.2%) was revealed. A positive relationship has been established between milk yield and days open (0.115, $p \leqslant 0.01$), milk yield and period of insemination (0.165, $p \leqslant 0.01$), days open and voluntary waiting period (0.257, $p \leqslant 0.01$), days open and period of insemination (0.955, $p \leqslant 0.01$). The dependence of the duration of days open and the voluntary waiting period on such paratypical factors as the age of cows and the month of their calving was examined. There is a tendency to reduce the duration of days open and the voluntary waiting period in cows with each subsequent lactation. It was identified that the duration of the voluntary waiting period was the greatest in cows that calved in November, March, and May, and the smallest – in August. Cows that calved in March had a longer duration of days open, and with calving in February – the shortest. Conclusions are drawn about the possibility of using the value of the period of insemination in selection programmes. The possibility of using reproduction level attributes in selection programmes is proved

Keywords: reproduction rate, period of insemination, milk production, voluntary waiting period, days open, Holstein breed

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Relevance

In the practice of breeding improvement of farm animals, there is a tendency to expand controlled traits for their further use in selection programmes. On the one hand, this is caused by the need to control new economically important attributes, and on the other – by the possibilities of genomics (Ruban *et al.*, 2019; Fedota *et al.*, 2018; Cole *et al.*, 2012), when selection based on genetic markers requires additional monitoring of changes in the phenotypic manifestation (Ruban *et al.*, 2016; Fedota *et al.*, 2016). Recently, this has led to the emergence of a new research area called phenomenon (Bilder *et al.*, 2009; Houle *et al.*, 2010). The term phenomenon reveals the need for more detailed (more regular in time) control of breeding traits (Greenwood *et al.*, 2016; Koltes *et al.*, 2019; Ruban *et al.*, 2019), and analysis of changes in these attributes reveals the features of the genotype-environment interaction (Ruban, 1999; Ruban, 1987).

Reproduction rates are known to have a substantial impact on the economy of production (Cole *et al.*, 2020), but in breeding, these traits have a weak genetic determination and are more dependent on livestock management and feeding (Ali *et al.*, 2019; Brzáková *et al.*, 2019). So the vast majority of successful fertilisation of a cow depends on the professionalism of the artificial insemination technician and the veterinarian, who monitor the state of recovery processes in the period after calving. The system for monitoring the state of reproduction of cows additionally includes such a feature as the waiting period (Mitioglo *et al.*, 2017), which allowed testing the working hypothesis regarding the possibilities of using this indicator in the breeding process.

Analysis of recent studies and papers

A voluntary waiting period or VWP is defined as the interval from the date of calving to the date of the first insemination of a cow, made by a specialist based on an assessment of the state of the cow›s reproductive organs, or other management decisions (Fleming *et al.*, 2019). The duration of this period is substantially influenced by the artificial insemination technician or veterinarian, based on an assessment of the general condition and a thorough examination of the cow›s reproductive organs (Miller *et al.*, 2007). VWP is influenced by the specific features of calving planning, the use of sexual heat synchronisation schemes, and most importantly, the qualification of veterinarians and artificial insemination technicians, so the value of this period varies greatly between farms and animals of the same herd (Fleming *et al.*, 2019).

The most common reasons for changing the duration of this period were the condition of cows after calving – 50%, the calving season – 18%, the productivity level – 18%, the calving number – 14%, and other reasons – 14% (Dejarnette *et al.*, 2007)

In the conditions of Dutch farms, the optimal VWP was 6 weeks. The average economic losses from extending the VWP for more than 6 weeks were 9, 26, and 52 euros for the duration of the waiting period of 9, 12, and 15 weeks, respectively (Inchaisri *et al.*, 2011). In the practice of North American dairy farms, VWP within 60 days (8.5 weeks) is considered normal (Miller *et al.*, 2007; Stangaferro *et al.*, 2018).

In tropical climates, the calving season has a substantial impact on VWP values (Silva *et al.*, 2017).

Relationships were found between VWP of less than 50 days, the period of days open – DO with the corresponding probability value ($p \leqslant 0.05$), and fertilisation in the first 200 days of lactation ($p \leqslant 0.01$), compared with the period of voluntary waiting that was more than 50 days (Fodor *et al*., 2018)

VWP lasting 45 to 70 days was associated with a shorter rumination time during estrus and a lower pregnancy index after the first insemination (Yazlık *et al*., 2018).

According to the data (Ali *et al*., 2019), the heritability ratio (h^2) of the DO interval in different livestock breeds was 0.09±0.121, and a substantial genetic correlation was also found between DO and milk yield during lactation (r=0.24; $p \leqslant 0,01$). This means that selection to increase milk yield affects the increase in DO duration.

In herds of the Swiss breed in the United States, the genetic correlation between DO and milk forms, DO and the height of posterior udder attachment was positive – 0.52 and 0.55, respectively, and between the duration of the service period and productive life was negative – -0.60 (Gibson & Dechow, 2018).

Purpose of the study. The purpose of the study was to determine the influence of the father factor on the duration of the voluntary waiting period (VWP), days open (DO), and period of insemination (PoI), the task was to determine the relationship of these periods with each other, and with milk productivity, assess the impact of paratypical (organised) factors on them.

Materials and Methods

The study was conducted in the conditions of an agricultural Ltd "Agroko", Chornobai district, Cherkasy region. A sample was formed for analysis.

The animals were kept using a tethered system and milked into a milk pipeline. Cows were fed a mixed diet, which was balanced in terms of energy, protein, and vitamin-mineral components.

Insemination of cows was conducted by a technique of artificial insemination by rectocervical method. Ultrasound examinations recorded the presence or absence of problems of the sexual apparatus (ovarian cyst or hypofunction, subclinical and clinical endometritis), after which a decision was made regarding the possibilities of insemination. A portable ultrasound scanner was used to evaluate the results of fertilisation, and the control was performed by a veterinarian. The results were entered into a computer herd management programme – Uniform Agri, the database of which stores information about the reproduction of herd animals (dates of calving, insemination, launch, number of the producer whose sperm was used for insemination), and signs of productivity (hopes, etc.).

Mathematical data processing was performed using IBM SPSS Statistics and using programme modules such as general linear model, graphical, correlation, and regression analysis.

The main intervals (attributes) that comprehensively characterise the complex process of cow reproduction and were used for analysis are shown in Fig. 1. For this purpose, the international terminology regarding these intervals is used, which is regulated by the International Committee for Animal Recording (ICAR). Additionally, such a feature as the period of insemination is highlighted – PoI. The PoI value was calculated for each cow as the difference between the DO and VWP values.

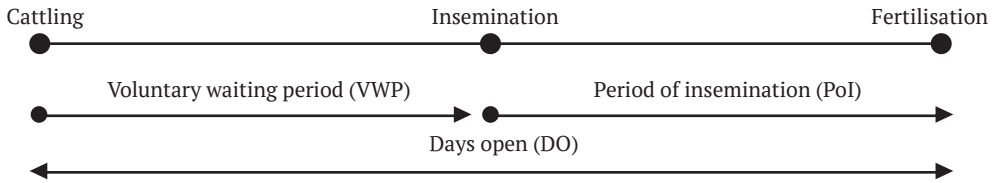

Figure 1. Attributes that characterise the level of reproduction of a cow

Paternal origin (the father factor) was used as a fixed genetic factor to calculate the genetic influence on breeding traits. The sample of cows was divided into two maximum equal groups, depending on the size of milk yields and considering the nature of the sample distribution to determine changes in the duration of the estimated periods (VWP, DO, PoI) from the level of productivity (Fig. 2). Based on the nature of the distribution, two almost equal groups were formed. Thus, cows that had a lactation yield of less than 8777 kg were included in the low-productive group (n=287), and in accordance with the milk yield of the higher number, a group of highly productive cows was formed (n=316).

Results and Discussion

The productivity of controlled cows was in the range of 4500-14000 kg of milk without the existing values of asymmetry and excess. The maximum productivity is recorded at 14 tons per cow. The sample was presented by originating from 18 breeding bulls of the Holstein breed (import of sperm from the USA, Canada).

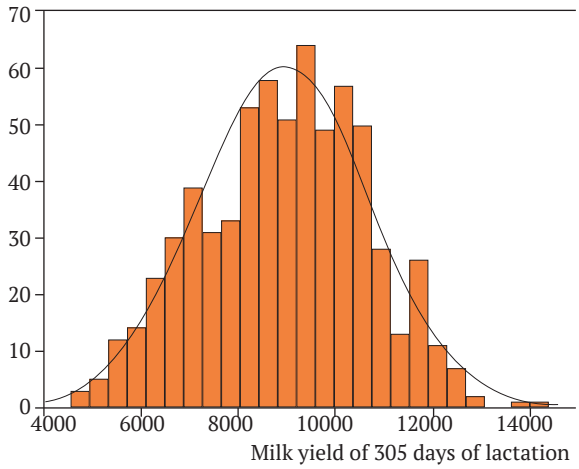

Figure 2. Value of the normal distribution of herd cows by milk yield (total 605 heads)

The highest average milk yield over 305 days of lactation was detected in Armstrong's daughters, whose productivity exceeded Audacity's offspring by 906 kg of milk and, respectively, by 755 kg compared to the herd average (Table 1). Armstrong's daughters were also characterised by the shortest DO period (98 days) and the longest voluntary waiting period (59 days). Cows offsprings of Audacity, in addition to the lower milk yield, were characterised by the longest DO value.

Table 1. *Values of productivity indicators and reproduction characteristics in daughters of different producers*

Producer	Number of cows	Milk yield for 305 days of lactation, kg	Periods, days		
			VWP	PoI	DO
		M±m	*M±m*	*M±m*	*M±m*
Matrix	24	9326±260.9*	66±3.0	52±14.5	118±14.3
He ET	76	9476±152.7***	65±3.5	78±8.9	147±16.3
Billtest	39	9254±225.9*	60±3.0	87±14.0	147±17.7
Audacity	26	8626±319.9	74±5.4	53±9.9*	152±22.4
Armstrong	26	9532±238.9***	59±2.1	38±8.9***	98±9.5**
Benjamin	68	8928±203.0	75±9.8	71±7.9	150±17.1
Other	316	8169±102.8***	78±11.0	77±4.5	154±19.2
Total	605	8777±67.8	72±8.5	72±3.1	146±17.8

Note: ** p⩽0.05; ** p⩽0.01; *** p⩽0.001*

There was also a substantial variability between producers over the period of insemination – PoI. Thus, the average value of this trait ranged from 38 days (Armstrong's daughter) to 87 days (Billtest's daughter). This trend coincided for the daughters of these producers with the average duration of the voluntary waiting period. A longer voluntary waiting period was characterised by cows from producer Benjamin (75 days), which is 5% more than the average value of this indicator for the herd. In this regard, the degree of influence of the father factor on the main breeding characteristics was evaluated (Table 2).

Table 2. *Assessment of the influence of the "parent" factor on the evaluated attributes (n=605 heads)*

Attribute	Degree of influence	F	Probability
Milk yield of 305 days of lactation	0.115	4.212	0.000***
VWP	0.027	0.890	0.592
DO	0.054	1.852	0.017***
PoI	0.052	1.758	0.027***

Note: ****– p⩽0.001*

It was identified that the influence of the father factor on the variability of the evaluated traits ranged from 2.7 to 11.5%. The probable influence of the genetic factor analysed on VWP was not confirmed, along with this, a substantial effect was determined on such signs as milk during 305 days of lactation (0.115, $p \leqslant 0.001$), PoI interval (0.052, $p \leqslant 0.001$) and DO (0.054, $p \leqslant 0.001$).

Analysis of correlation links between milk yield for 305 days of lactation and the period of days open was positive +0.257 ($p \leqslant 0.01$), which indicates a deterioration in the reproduction function with increased milk yield. Signs such as DO and PoI had a positive substantial correlation with milk yield at 305 days of lactation ($p \leqslant 0.01$) (Table 3).

Table 3. *Correlation coefficients between the main breeding characteristics of cows*

Paired attributes	Correlation coefficient
VWP –DO	0.257**
DO – milk yield of 305 days	0.115**
VWP – Milk yield of 305 days	-0.141**
DO – PoI	0.955**
PoI – Milk yield of 305 days	0.165**

Note: ***– p≤0.01*

With a decrease in VWP values, there is an increase in milk yield in cows (*r*=-0.141), which indicates the best recovery processes in cows in the post-calving period.

Regression analysis between the duration of the service period and milk yield during lactation showed that with an increase in milk yield by +3.38 kg, the duration of the service period increases by 1 day (Fig. 3).

Frequency distribution over the period of insemination (Fig. 4) proves that in the analysed sample, cows are most often found with a duration in the range of up to 50 days (terms of manifestation of two sexual cycles), which indicates a relatively high level of fertilisation and especially after passing the period of voluntary waiting, which was characterised by the restoration of sexual functions in cows.

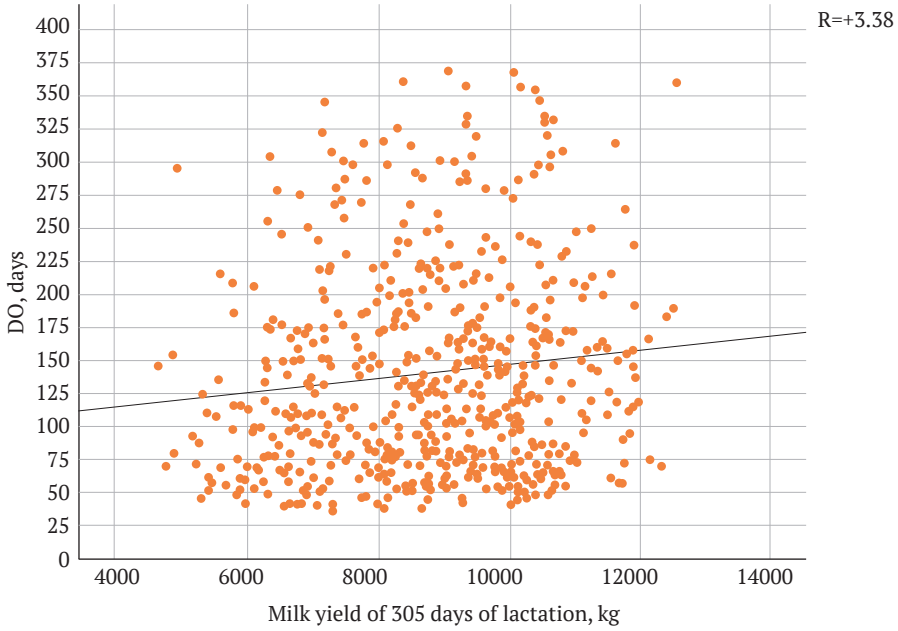

Figure 3. Distribution and regression relationship between milk yield at 305 days of lactation and the DO value in cows (*r*=+3.38)

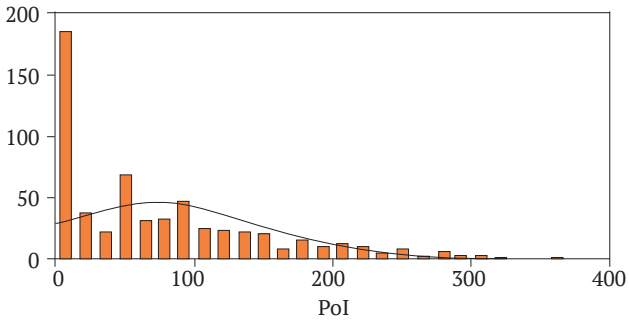

Figure 4. Distribution of herd cows by value (PoI)

Some cows were successfully fertilised in the following time periods, which is primarily due to the level of productivity and such consequences as a negative balance in live weight, the degree of fatness. So the data in Table 4 demonstrates that for the group of highly productive cows, there is a substantial difference for all periods included in the analysis (VWP, DO, PoI) compared to the low-performance group.

Table 4. *Elongation dependence of VWP, DO, and PoI depending on the performance level*

Group	Heads	Milk yield, kg	Duration, days		
			VWP	DO	PoI
Low-performance-	287	7391±59.0	70±1.30	137±4.78	66±4.46
High-performance-	316	10230±53.2	65±0.94	148±4.58	82±4.56
Difference between groups	-	-2839***	**-5.2*** **	**+11.00****	**+16.00****

Note: ***p≤0.01, ***– p≤0.001*

The possible changes in the duration of VWP, DO, and PoI periods from the cow's lactation age (Fig. 5) and the calendar month of calving, or the period of the year were analysed.

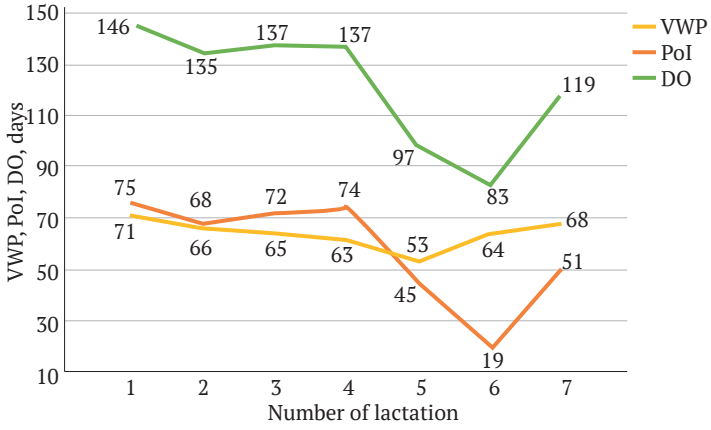

Figure 5. Dependence of DO, VWP, and PoI periods on the cow's lactation number

There is a general tendency to reduce the lengthening of periods that characterise the level of reproduction with the age of lactation (up to the sixth lactation), which indicates a better level of reproduction in full-aged cows than in first-calved and second-calved cows. The duration of the voluntary waiting period and the period of days open varied substantially depending on the month of calving of cows in the herd (Fig. 6). Thus, the longest duration of DO was in cows that calved in March, which indicates a modifying effect of environmental factors on this trait. A study by American specialists (Oseni *et al.*, 2003), which was conducted on Holstein cows in various farms, noted that cows that calved in March had the longest period of days open.

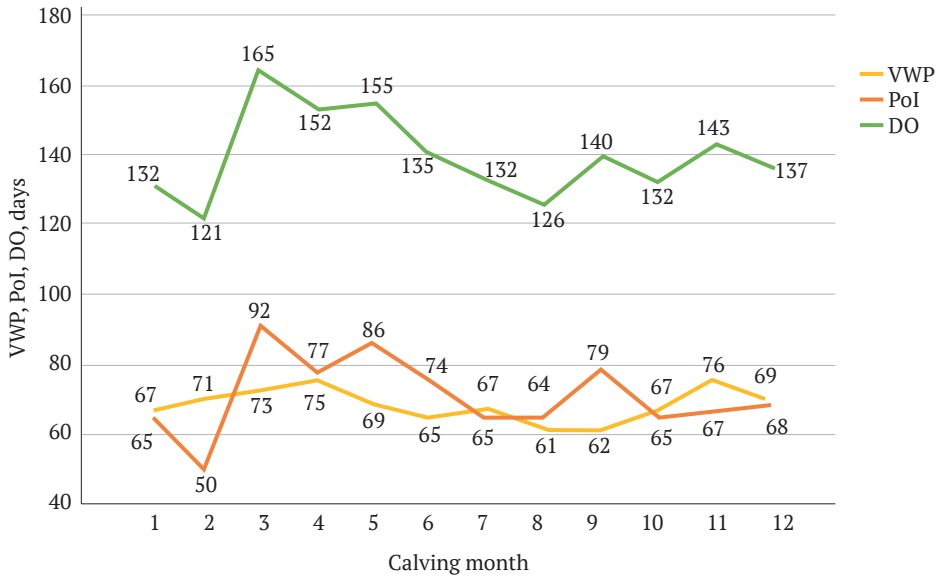

Figure 6. Dependence of DO, VWP, and PoI periods on the cow's calving month

Thus, a group of important traits was identified and a general scheme was developed for the correct assessment of the influence of genetic and non-genetic factors on the level of reproduction.

Detailed research in this area will continue if more representative samples are formed.

Conclusions and Prospects

1. A substantial influence of the father factor on such signs as milk yield of 305 days of lactation (0.115, $p \leq 0.001$), period of insemination (0.052, $p \leq 0.001$), and the period of days open (0.054, $p \leq 0.001$) was identified, which allows improving these traits by breeding.

2. Possible changes towards increasing the duration of DO and PoI with an increase in the level of productivity of cows were established.

3. The dynamics of changes in the characteristics of the level of reproduction depending on the age of cows and the month of calving is noted, which indicates the need to assess the influence of these factors when constructing a general model for assessing genetic value.

4. The substantial variability of the period of insemination among the daughters of different

producers indicates the possibility of using this indicator to correctly assess the influence of genetic and non-genetic factors, provided that more representative samples are formed.

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Генетична детермінація ознак рівня відтворення в молочному скотарстві

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Анотація. Актуальність дослідження обумовлена необхідністю контролю економічно важливих ознак відтворення молочної худоби, які мають слабку генетичну детермінацію та суттєво залежать від менеджменту і годівлі корів. Мета досліджень – визначити зв'язок між тривалістю добровільного періоду очікування, відкритих днів та періоду осіменінь, а також оцінити вплив на них фактору «батько». Проведено дослідження впливу генетичних та факторів зовнішнього середовища на добровільний період очікування, відкриті дні та молочну продуктивність. Виділено нову ознаку – період осіменінь, яка визначалась як різниця між подовженістю періоду відкритих днів та добровільного періоду очікування. Дослідження проводились на коровах голштинської породи (всього 605 гол), середній надій яких склав 8777 кг. Як джерело первинної інформації були використанні дані програми Uniform Agri, обробка яких здійснювалась з використанням дисперсійного та кореляційно-регресійного аналізу. Виявлено вірогідний вплив фактору «батько» на надій за 305 днів лактації (11,5 %), відкриті дні (5,4 %), період осіменінь (5,2 %). Встановлено позитивний зв'язок між надоєм і відкритими днями (0,115, $p \leqslant 0,01$), надоєм та періодом осіменінь (0,165, $p \leqslant 0,01$), між відкритими днями і добровільним періодом очікування (0,257, $p \leqslant 0,01$) та між відкритими днями і періодом осіменінь (0,955, $p \leqslant 0,01$). Досліджено залежність тривалості відкритих днів і добровільного періоду очікування від таких паратипових факторів, як вік корів та місяць їх отелення. Відмічена тенденція зменшення тривалості відкритих днів та добровільного періоду очікування у корів з кожною наступною лактацією. Встановлено, що тривалість добровільного періоду очікування була найбільшою у корів, які отелилися у листопаді, березні, травні, а найменшою – у серпні. Корови, які отелились в березні мали більшу тривалість відкритих днів, а з отеленням в лютому – найкоротшу. Зроблені висновки про можливості використання значення періоду осіменінь в програмах відбору. Доведена можливість використання ознак рівня відтворення в програмах відбору

Ключові слова: рівень відтворення, період осіменінь, молочна продуктивність, добровільний період очікування, відкриті дні, голштинська порода