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Influence of Lactation Number, Year and Season of Calving on Milk Productivity of Cows

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Abstract. The main characteristics of the milk productivity of Holstein dairy cattle differ in different countries due to differences in terrain, management and breeding objectives. At the same time, the manifestation of non-genetic (that is, environmental) factors during milk production, as a rule, mask the real breeding value of animals. The main goal of this study was to analyze the influence of lactation number, year and season of calving on the milk productivity of 238 Holstein cows during a 4-year period (2014-2017). The study was conducted using primary data on the dairy productivity of livestock in the conditions of PJSC Plemzavod Stepnoi of the Kamian-Dnipro district of the Zaporizhia region.The following characteristics were evaluated for each animal: duration of lactation, hope for 305 days of lactation, hope for the entire lactation, fat content and protein content in milk. P. Wood's model was used to approximate lactation curves within each subgroup. All signs of milk productivity were analyzed based on the algorithm of one- or two-factor analysis of variance with fixed factors using the statistical package STATISTICA v. 6.0 (Statsoft Inc.).Lactation number was found to have a significant effect on all milk yield traits that were examined (in all cases: $p<0.001$). Hope for 305 days of lactation increased with the growth of lactation number. The highest values of this characteristic were noted during the 2nd and 3rd lactations. The lowest estimate of milk yield for 305 days of lactation of dairy cows of this farm was obtained in 2014, and the highest in 2016. The calving season probably influenced the indicators of milk productivity (primarily, the content of fat and protein in milk) of firstborns. In addition, the milk yield score at 305 days of lactation was lower among winter- or spring-calved gilts compared to fall-calved animals. No influence of the calving season was noted among adult cows. Lactation number and year of calving probably influenced the estimates of the coefficients and parameters of P. Wood's model. The shape of the lactation curves of firstborns was flatter compared to mature cows. Estimates of peak milk yield were lower, but the index of constancy of the lactation curve was higher during the 1st lactation. Thus, we found that obtaining real (unbiased) estimates of milk productivity traits of Holstein cattle requires preliminary adjustment of data regarding the influence of lactation number, year and season of calving

Keywords: milk productivity, number of lactations, year and season of calving, P. Wood model, dairy cattle

INTRODUCTION

Improving the productivity of dairy cattle requires an understanding of the factors that affect this productivity. Among the factors of the external environment, it is possible to distinguish factors that can be measured (animal age, year, season of the year, milking frequency, etc.) and factors with an unmeasured influence (infectious diseases, parasitic infestations, etc.). Accordingly, the first of them can be identified and used in dairy farm management. Housing and feeding conditions, lactation number (or age of the animal), year and season of calving are the leading environmental factors affecting the efficiency of lactation performance of cattle. In addition, breed affiliation, stage of lactation and frequency of milking also affect the level of milk productivity [1].

On the other hand, the use of the test-day model makes it possible to increase the assessment of the genetic value of breeding stock by 4…8%, and the prediction of milk yield of dairy cows based on the characteristics of their lactation curves is considered an important management tool in dairy farming [2].

The peculiarity of the lactation curve is that milk production per unit of time is peaked and shifted to the right. The variety of mathematical formulas presented in the literature that can be used to model the lactation

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curve is due to the fact that each of them fits certain sets of empirical data better than others. In order to provide significant adequacy to the original data, the shape of the fitted curve must be sufficiently flexible. One of the most widely used formulas for describing the lactation curve is the incomplete gamma function proposed by P. Wood [3]. In addition, P. Wood's model can adequately approximate the dynamics of fat content in milk during lactation, which was recently demonstrated for Holstein cows in China [4].

A more important characteristic of the lactation curve is its persistence, which reflects how quickly the daily milk yield decreases after reaching the peak level of productivity. It has higher values in animals that have lower milk yields and reach peak milk productivity later. The analysis of the relationship between the constancy of the lactation curve of cows and other functional characteristics of their milk productivity in [5] showed that genetic improvement of this indicator is possible and favorable.

In addition, the age of insemination of heifers is an important factor affecting the assessment of the stability of the lactation curve. Thus, in work [6] it was shown that the shape of the lactation curve of heifers that calved at a younger age tended to be lower and flatter than for heifers that calved at an older age; the latter are characterized by a sharper rise in the lactation curve and its subsequent faster decline after reaching the peak of productivity.

It was established [7] that the estimates of the heritability coefficient (h2) of the parameter of constancy of the lactation curve of Holstein cows during the first three lactations had a tendency to decrease, mainly due to the increase in the value of the residual variance, and were 0.17, 0.16 and 0. 14, respectively. The estimation of genetic correlation coefficients between the parameter of constancy of the lactation curve for different lactations was 0.26 (between the 1st and 2nd), 0.32 (between the 2nd and 3rd) and 0.23 (between the 1st and 3rd lactations).

During the study of paratypical factors that influenced the variability of the lactation curves of Holstein and Jersey cows, the likely influence of the lactation number and the calving season on the coefficients of P. Wood's model, as well as on the indicator of the constancy of the lactation curve, was established. At the same time, a probable combined effect of "lactation number × calving season" on the accuracy of approximation of actual data by this model was found (estimation of the coefficient of determination R^2). On the other hand, the probable influence of the "year of calving" factor on the estimates of P. Wood's coefficients was noted only among cows of the Jersey breed, but not among Holstein cows [8].

As indicated in the paper [9], the influence of the lactation number on the estimates of the coefficients and indicators of P. Wood's model can be explained by the fact that the older the animal, the higher its lactation begins with higher milk yields, but since at a certain stage of the lactation activity there is an inhibitory effect of body size (regardless of the level of productivity), the rate of decline in milk productivity is higher in more mature cows. That is, body weight has a more significant inhibitory effect on the productivity of adult animals due to their higher productivity [9]. At the same time, the influence of lactation number was more noticeable for breeds bred in tropical regions than among European and American breeds of cattle [10].

Another explanation for the influence of the lactation number on the shape of the lactation curve may be the presence of a difference in the rate of depletion of the body; adult cows use their reserve much faster in the earlier stages of lactation, which leads to higher values of the coefficient "b" and, conversely, to lower values of the coefficient "c" of P. Wood's model, than among first-born cows [9]. Accordingly, the later period of peak milk yield among first-borns compared to adult cows can be explained by differences in rates of depletion of body reserves between adult cows and heifers. Higher rates of exhaustion in the early stages of lactation in adult cows lead to an early peak of productivity [8; 9]. Climatic factors also significantly affect the estimates of the coefficients and parameters of P. Wood's model. At the same time, the estimates of total and peak hope are the lowest among cows that calved in the summer due to a limited feeding ration and the effect of heat stress [11].

Since most studies of the influence of the year and season of calving on the level of milk productivity of Holstein cows, as cited above, were conducted in arid and hot climates [1; 8; 10; 11], the results of a similar analysis in the conditions of the temperate climate of Ukraine deserve special attention .

The purpose of this study was to analyze the influence of lactation number, year and season of calving both on the total milk productivity of cows and on the peculiarities of the formation of their lactation curves.

MATERIALS AND METHODS

Primary data on the milk productivity of Holstein cattle in the conditions of PJSC Plemplant Stepnoi of the Kamian-Dnipro district of the Zaporizhzhya region (n=238 heads) served as the material for the work. Data for the first three lactations of animals that calved during 2014-2017 were included in the analysis.

The following traits were evaluated for each animal: duration of lactation (DIM), 305 day lactation (MY305), total lactation (TMY), milk fat content (FP) and milk protein content (PP). In addition, the daily expectation of animals was determined for 10 control days (TD1-TD10), corresponding to the 30th, 60th, 90th, etc. days of lactation If data for a certain control day were missing for the corresponding animal, the daily intake estimate was calculated by linear interpolation for the two days before and after the control date, respectively.

For each feature, the arithmetic mean value and its error (Mean±SE) were calculated. Testing of the hypothesis regarding the lack of influence of lactation number, year of calving and season of calving on the characteristics of milk productivity was carried out based on the algorithm of one- or two-factor analysis of variance (ANOVA) with fixed factors.

The seasons of the year were defined as follows: winter (December – February), spring (March – May), summer (June – August) and autumn (September – November).

P. Wood's model [3] was used to approximate the lactation curve based on data for 10 control days:

$$Yt=ab^{t}e^{(-ct)} \qquad (1)$$

where Yt is daily hope (in kg) at time t (control days from TD1 to TD10); a – initial hope; b – the rate of growth of hope until reaching the peak; c is the rate of decrease of the load after reaching the peak.

The estimate of peak yield (in kg) was calculated according to the formula:

$$Ymax = a\left(\frac{b}{c}\right)^{b} e^{-b} \qquad (2)$$

and the moment of reaching peak fertility (in days) according to the formula:

$$Tmax = \frac{b}{c} \qquad (3)$$

Persistence of the lactation curve (persistence) in P. Wood's model was calculated according to the formula:

$$St=c^{-(b+1)} \qquad (4)$$

The quality of the approximation of the initial data by P. Wood's model was evaluated on the basis of the coefficient of determination (R^2).

All statistical calculations were carried out using the algorithms described in the manual [12] using the software STATISTICA v. 6 (StatSoft Inc.).

RESULTS AND DISCUSSION

Effect of lactation number. It was established that the number of lactation probably influenced all the investigated signs of milk productivity of cows (Table 1).

Table 1. *Indicators of variability (Mean±SE) of signs of milk productivity of cows depending on the lactation number*

Lactation	n	DIM, days	TMY, kg	MY 305, kg	FP, %	PP, %
I-a	238	337.9±4.8	10224.0±153.5	9374.8±84.5	4.26±0.01	3.28±0.01
II-a	238	377.8±7.9	12277.0±241.9	10711.6±127.7	4.30±0.01	3.30±0.01
III-я	107	357.7±9.7	11567.8±342.6	10631.4±247.8	4.30±0.01	3.30±0.01
F(2; 579)	–	452.50	16.04	34.81	26.53	23.03
p	–	<0.001	<0.001	<0.001	<0.001	<0.001

The average duration of lactation significantly exceeded 305 days and varied from 337.9 (for first-borns) to 377.8 days (during the second lactation). A similar pattern was noted in relation to the total milk yield – it ranged on average from 10,224.0 (for first-borns) to 12,277.0 kg (during the second lactation). The first-borns were also characterized by the lowest estimate of milk yield for 305 days of lactation (9374.8 kg), which was significantly inferior to the corresponding estimates obtained for animals of the experimental herd during the II and III lactations.

Qualitative characteristics of milk productivity also showed age variability – both the protein content and the fat content in milk increased in full-aged cows compared to first-born cows (see Table 1).

As might be expected, age-related differences in the level of milk production were closely related to the shape of the lactation curve of the animals. In general, firstborns were characterized by relatively low and more or less stable milk yields at different stages of lactation, and during the II and III lactations, the shape of the lactation curves acquired a typical shape with a rapid increase at the beginning and a gradual decrease in daily milk yields after reaching the peak value (Fig. 1).

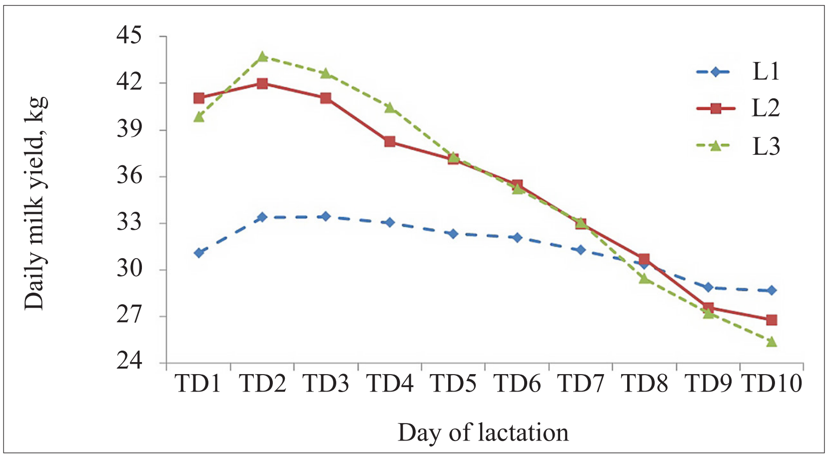

Figure 1. *Lactation curves of cows depending on lactation number (L1-L3)*

In general, probable differences between the daily milk yields of animals depending on the lactation number were noted on control days TD1-TD6 (one-way analysis of variance: in all cases p<0.001) and for TD10 (p=0.023). The obtained lactation curves were quite well approximated by P. Wood's model – the coefficient of determination (R^2) estimates for animals of different groups ranged from 97.66 to 99.42% (Table 2).

The first-borns were characterized by the lowest estimates of the coefficients "a" and "c" of P. Wood's model and, accordingly, the minimum amount of peak lactation (*Ymax*), but at the same time, their lactation curve had the highest assessment of indicators of constancy (St) and the moment of reaching peak lactation (*Tmax*). While during the 2nd and 3rd lactations, the animals of the experimental herd had the highest estimates of the coefficients "a" and "c" of the Wood model, as well as a high value of the peak yield when it was reached earlier, but a lower constancy of the lactation curve (see Table 2).

Table 2. *Coefficients and indicators of P. Wood's model of the lactation curve of cows depending on the lactation number*

Lactation	*a*	*b*	*c*	R^2, %	*St*	*Tmax*, days	*Ymax*, kg
I	32.83±0.24	0.149±0.014	0.049±0.004	97.66	32.0	92.7	33.4
II	44.87±0.47	0.157±0.022	0.089±0.006	99.25	16.5	53.8	41.9
III	45.57±0.49	0.270±0.022	0.123±0.006	99.42	14.3	67.0	43.0

A plausible effect of lactation number on milk yield traits has previously been demonstrated for Holstein cattle kept on a large commercial farm in Mexico. Thus, the yield of first-borns for 305 days of lactation was 7607±145 kg of milk, while among adult animals (6th lactation and above) it reached 9548±181 kg of milk. The total weight gain per lactation of firstborns was about 4500 kg less than the similar indicator of adult cows, which was 13544±5491 kg with an average duration of lactation of 454±154 days [13].

Similar results were obtained for Holstein cows in the conditions of Arizona (USA). The average yield of milk among firstborns was 6656±193 kg, and during the II, III and IV lactations – 7335±193, 7769±193 and 7894±194 kg, respectively. The maximum manifestation of hope was reached during the 5th lactation and in older cows [14].

For animals of the same breed under the conditions of Turkey, it was established that the firstborns were significantly inferior in terms of the level of milk yield for 305 days of lactation (5885±48 kg) to the estimates obtained during the II lactation (6096±55 kg), but in the future, a tendency to a gradual decrease was observed decrease in milk yield during the fifth lactation [15].

For Holstein cows in the arid conditions of North Africa (Tunisia), it was also established that firstborns were characterized by a low level of milk productivity (5412±52 kg), and during the II and III lactations it increased significantly (5721±55 and 5614±47 kg, respectively). Although in the future, the amount of milk obtained gradually decreased until the 5th lactation [1].

Thus, the reviewed studies demonstrated that milk production increases with increasing lactation number and is maximized during IV or V lactation. This may be associated with an increase in the size of the udder and an increase in the number of secretory cells in adult animals [16]. At the same time, the influence of lactation number on the level of milk productivity may vary depending on the year of its initiation [17].

Effect of year of calving. As for the influence of the year of calving, the highest estimate of the average duration of lactation was noted for cows of the II lactation that calved in 2016 (405.7 days). Accordingly, these animals also had the highest estimate of the total yield (13.155.0 kg). On the other hand, the highest estimate of milk yield for 305 days of lactation (11.210.2 kg) was noted for cows of the 3rd lactation, which also calved in 2016 (Table 3).

Table 3. *Indicators of variability (Mean±SE) of signs of milk productivity of cows depending on the year of calving and lactation number*

Year of calving	**n**	**DIM. days**	**TMY. kg**	**MY305. kg**	**FP. %**	**PP. %**
			I-st lactation			
2014	61	353.1±11.6	10396.8±329.7	9215.9±117.8	4.14±0.02	3.21±0.01
2015	107	335.6±6.3	9997.6±222.5	9212.5±130.1	4.30±0.01	3.30±0.01
2016	67	330.3±8.1	10555.0±261.0	9843.4±170.2	4.30±0.01	3.30±0.01
F(2; 232)		1.75	1.32	5.94	162.33	170.11
p		ns	ns	0.003	<0.001	<0.001
			II-nd lactation			
2015	59	381.1±19.1	12340.2±503.2	10589.2±201.5	4.29±0.01	3.29±0.01
2016	105	405.7±12.7	13155.0±392.9	10980.7±177.1	4.30±0.01	3.30±0.01

Table 3, Continued

Year of calving	n	DIM. days	TMY. kg	MY305. kg	FP. %	PP. %
2017	72	337.7±7.2	11082.6±316.3	10488.0±284.0	4.31±0.01	3.31±0.01
F(2; 232)		4.89	5.02	1.31	6.20	5.11
p		0.003	0.002	ns	0.001	0.001
			III-rd lactation			
2016	49	394.4±17.0	12883.5±514.7	11210.2±330.3	4.30±0.01	3.30±0.01
2017	56	327.1±9.5	10429.4±421.3	10112.3±363.8	4.32±0.01	3.30±0.01
F(1; 103)		12.80	13.86	4.89	8.14	3.30
p		0.001	<0.001	0.029	0.005	ns

Note: *ns – p>0.05*

In general, no effect of year of calving was noted only for duration of lactation and total milk yield among first-borns, milk yield for 305 days of lactation during the 2nd lactation and protein content in milk during the 3rd lactation. Thus, in most cases, the year of calving probably influenced the quantitative and qualitative characteristics of milk productivity of cows of the experimental herd.

In general, the animals that calved in 2016 (taking into account the influence of the lactation number) were characterized by the highest estimates of milk productivity in comparison with 2014, 2015 and 2017 (see Table 3).

A combined effect of lactation number and year of calving was noted only for milk fat and protein content (two-way analysis of variance with fixed factors: $p < 0.001$ in both cases). This may be due to the fact that both the protein content and the fat content of the milk were significantly lower for the firstborns that calved in 2014 than in the other groups (see Table 3).

Probable differences between daily milk yields depending on the year of calving were noted for first-borns on all control days (in all cases $p<0.05$), except for the first two (TD1-TD2). During the 2nd lactation, on the contrary, the daily milk yield for separate control days did not differ among animals that calved in different years; only milks for TD2, TD3 and TD8 were excluded (in all cases $p<0.05$). Finally, during the third lactation, a significant effect of year of calving was noted for daily milk yield in the second half of lactation (TD6-TD8) (in all cases $p<0.05$).

Approximation of lactation curves by P. Wood's model for experimental animals of different calving years and lactation numbers was also quite high – the coefficient of determination (R^2) estimates in most cases amounted to 95...98%, with the exception of firstborns that calved in 2014 (Table 4).

Table 4. *Coefficients and indicators of the P. Wood model of the lactation curve of cows depending on the year of calving and lactation number*

Year of calving	*a*	*b*	*c*	R^2. %	*St*	*Tmax*. days	*Ymax*. kg
			I-st lactation				
2014	33.49±1.46	0.085±0.075	0.043±0.015	91.43	30.3	60.2	32.6
2015	32.83±0.21	0.106±0.012	0.042±0.003	98.30	33.5	77.3	32.6
2016	32.86±0.36	0.206±0.021	0.056±0.005	94.90	32.2	111.8	34.9
			II-nd lactation				
2015	43.34±0.58	0.089±0.028	0.067±0.007	98.40	19.1	40.8	40.7
2016	45.35±0.68	0.132±0.031	0.080±0.008	98.29	17.4	50.1	42.4
2017	45.77±0.86	0.261±0.040	0.124±0.011	98.33	13.8	63.9	42.8
			III-rd lactation				
2016	46.09±0.68	0.261±0.031	0.115±0.008	98.74	15.3	69.4	44.0
2017	45.28±1.11	0.292±0.052	0.135±0.014	97.42	13.2	65.8	42.3

It was established that both the year of calving and the lactation number had a significant effect on the estimations of lactation stability (St) obtained for different groups of animals (two-way analysis of variance with fixed factors: in both cases $p<0.05$). As for the peak yield, only a probable effect of lactation number ($p=0.007$) was established, while the moment of peak yield (*Tmax*) for different groups of animals showed completely random variability and did not depend on the factors used in the analysis (see table 4).

The effect of year of calving was established for Holstein cows under the conditions of Turkey. The lowest level of milk productivity for 305 days of lactation was noted in 1995 (4391±109 kg), but further its gradual increase was observed, reaching a maximum in 2004 (7280±81 kg). The reasons for this increase may be the use of bulls with high genetic ability, effective breeding for milk yield, high intensity of culling of animals from the herd, and improvement of conditions for keeping and feeding dairy cows [15].

For Holstein cows in the arid conditions of Tunisia, a probable influence of the year of calving on the level of milk productivity was also proven. At the same time, the lowest estimate of yield in 305 days (4879±118 kg) was noted in 1998, and the highest (6251±186 kg) in 2003. It has been established that such fluctuations can be associated with changes in herd size, age of animals and improvement of dairy herd management practices implemented from year to year [1].

Influence of calving season. A certain influence of the calving season on the characteristics of milk productivity was established only among firstborns (Table 5). At the same time, an almost probable trend to interseasonal differences was established for fat in 305 days (p=0.057), primarily due to significant differences between the estimates of animals that calved in the winter period (8957.1 kg) and animals that calved in the summer or in autumn (9552.3…9606.9 kg).

Table 5. *Indicators of variability (Mean±SE) of signs of milk productivity of firstborns depending on the calving season*

Calving season	n	DIM. days	TMY. kg	MY305. kg	FP. %	PP. %
Winter	41	358.8±16.4	10429.2±536.8	8957.1±241.2	4.30±0.01	3.30±0.01
Spring	73	340.4±6.6	10182.7±238.1	9284.8±143.6	4.26±0.01	3.28±0.01
Summer	85	328.5±6.4	10130.9±212.1	9552.3±138.2	4.23±0.01	3.26±0.01
Autumn	38	331.5±8.1	10290.5±399.3	9606.9±181.1	4.31±0.01	3.30±0.01
$F(3; 232)$		1.74	0.16	2.54	8.79	6.82
p		ns	ns	0.057	<0.001	<0.001

For qualitative signs of milk production, the influence of the season of calving was highly probable (in both cases p<0.001) and was accompanied by higher estimates of fat and protein content in first-borns that calved in the cold seasons of the year (autumn-winter) and low – in the warm seasons of the year (spring-summer) (see table 5).

Probable differences between daily milk yields of firstborns depending on the calving season were noted for all control days (in all cases p<0.05), with the exception of the very last one (TD10). During the 2nd lactation, on the contrary, the daily milk yields for individual control days were likely to differ only during the first part of lactation (TD2-TD4) (in all cases p<0.05), that is, when the level of milk productivity is the highest. Finally, during the third lactation, a probable effect of calving season was noted for daily milk yield only at the beginning of lactation (TD1-TD2) (in all cases p<0.05).

Approximation of lactation curves by P. Wood's model for experimental animals of different lactation number and calving season was again high – the coefficient of determination (R^2) in most cases was 90…98%, with the exception of first-borns that calved in winter (Table 6). For first-borns (regardless of calving season), the lactation curves differed significantly from the typical shape, while during the II and III lactations, the shape of these curves was very close to the typical shape (Fig. 2)

Table 6. *Coefficients and indicators of the P. Wood model of the lactation curve of cows depending on the calving season and lactation number*

Calving season	*a*	*b*	*c*	*R²*. %	*St*	*Tmax*. days	*Ymax*. kg
I-st lactation							
Winter	31.90±1.12	0.109±0.069	0.043±0.017	65.11	33.1	78.2	31.7
Spring	31.56±0.31	0.097±0.019	0.031±0.005	90.17	45.3	95.9	32.0
Summer	33.64±0.52	0.201±0.030	0.058±0.007	91.67	30.3	105.0	35.3
Autumn	35.18±0.36	0.219±0.025	0.077±0.006	97.52	22.7	86.6	35.5
II-nd lactation							
Winter	46.89±0.89	0.183±0.041	0.107±0.011	98.21	14.1	52.1	43.1
Spring	43.96±0.87	0.101±0.042	0.073±0.011	96.99	17.8	42.2	41.1
Summer	43.32±0.54	0.172±0.026	0.089±0.007	98.85	17.1	59.1	40.9
Autumn	47.38±0.41	0.167±0.018	0.091±0.005	99.48	16.4	55.9	44.4
III-rd lactation							
Winter	49.32±1.07	0.132±0.047	0.093±0.012	97.47	14.7	43.2	45.3
Spring	42.30±1.60	0.306±0.081	0.139±0.021	94.41	13.2	67.3	39.7
Summer	42.41±0.53	0.340±0.026	0.133±0.007	99.19	14.9	77.9	41.5
Autumn	50.07±0.71	0.215±0.030	0.112±0.008	98.98	14.2	58.3	46.4

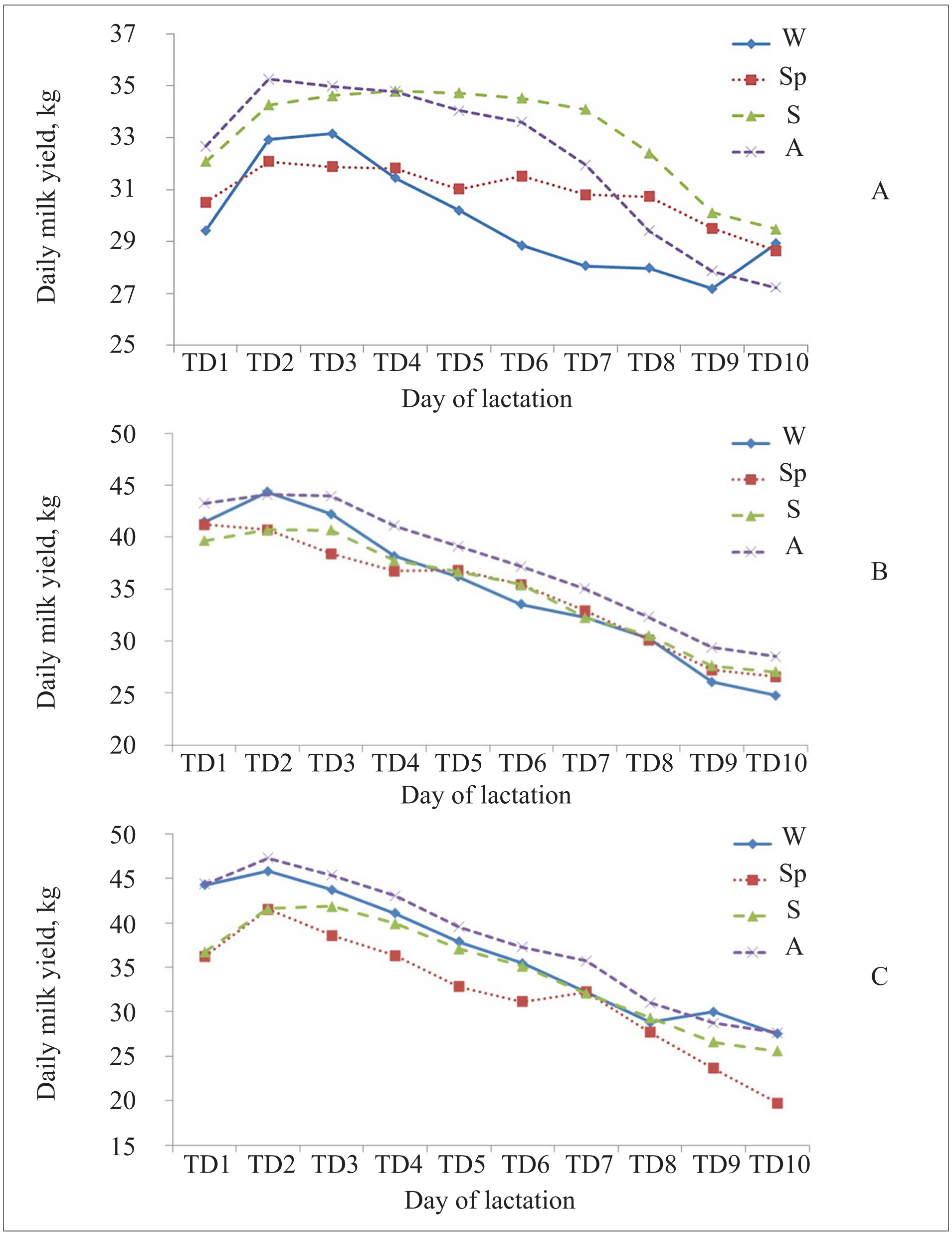

Figure 2. *Lactation curves of cows depending on the calving season of firstborns (A), animals of the II lactation (B) and III lactation (C): W – winter; Sp – spring; S – summer; A – autumn*

It was established that the calving season probably did not affect the estimates of lactation stability (St), peak milk yield (*Ymax*) and the moment of its achievement (*Tmax*) obtained for animals of different groups, while a probable influence was proved only in relation to the lactation number (two-factor variance analysis with fixed factors: in all cases p<0.01).

In work [13] it was shown that the milk productivity of Holstein cows during 305 days of lactation was lower in animals that calved in spring (8804±153 kg) and summer (8724±163 kg), in contrast to individuals that calved in autumn (9079±151 kg) or in winter (9085±143 kg).

In the conditions of Arizona (USA), the highest yield for 305 days of lactation was obtained from Holstein cows that calved in spring (7690±195 kg) and in winter (7765±193 kg), which significantly exceeded the corresponding estimates of animals calving in summer (7387±193 kg) or in autumn (7543±193 kg). A similar regularity was also noted in relation to the influence of the calving season on the total hope for the entire lactation [14].

It was also noted that these cows had a simultaneous influence on the level of milk productivity of both the lactation number and the calving season – firstborns that calved in the spring were characterized by a lower amount of milk in 305 days of lactation than animals with winter calvings (6625 and 6783 kg, respectively). At the same time, older animals did not show significant differences depending on the calving season. Moreover, for almost all groups of adult cows, the 305-day survival was much higher in animals that calved in the fall compared to females of the same age with summer calvings [14].

Thus, under the influence of heat stress, firstborns gave priority to growth and maintenance of their own viability due to milk synthesis. And cows that calved in spring and summer were obviously more sensitive to heat stress at the beginning of lactation, when their energy needs were the highest [14].

For Turkish Holsteins, the highest level of milk yield for 305 days of lactation was noted for cows with winter calvings (5890±64 kg), and the lowest – with summer calvings (5506±68 kg). For winter-calving cows, this was likely due to adequate feeding levels in the early months of lactation and the addition of alfalfa to the diet when milk yields began to decline. On the other hand, cows that calved in the summer had low milk yields due to the fact that they were exposed to high environmental temperatures in the first 3-4 months of lactation [15].

It was previously established that the season of calving affected the weight in 305 days and for Simmental cows – the highest weight (4819±82 kg) was also noted in animals with winter calvings, and the lowest estimate of this trait in cows that calved in summer (4477±81 kg) [18].

A highly probable effect ($p<0.001$) of the calving season on the 305-day lactation yield was also found for Tunisian Holstein cows – the highest scores (5827±69 kg) were given to animals calving in winter, while cows calving in summer yielded almost 614 kg of milk [1].

The effects of heat stress (on the basis of the THI coefficient) were studied on Holstein-Friesian cows in the conditions of Turkey [17]. It was proved that the milk yield of cows started to decrease slowly starting from April, and decreased sharply in May, when the value of the THI coefficient exceeded 65…70. During the summer months, when this value exceeded 70, the hope continued to decrease. However, milk yield started to increase again at the end of August and, finally, in October reached May values.

In general, P. Wood's model adequately described the initial data. Only for firstborns that calved in winter, the coefficient of determination was low (65.11%) and, accordingly, the shape of their lactation curve was atypical. It was previously established that in 15…42% of Holstein cows in the conditions of Tunisia, individual lactation curves may have an atypical shape [11]. And in work [19] it was shown that 26.3% of 1278 analyzed full lactation curves of Turkish Holstein cows in the conditions of Turkey had an atypical shape.

In work [10] it was noted the likely influence of the number of lactation on the constancy of the lactation curve; the lactation curves of firstborns of the Friesian × Bunaji cross had a flatter shape and a lower level of daily milk yield than adult animals. These authors also indicated that the milk productivity of firstborns is determined to a greater extent by environmental factors than the lactation activity of more mature cows [10].

Similar regularities in the formation of lactation curves of Holstein cows in the conditions of Tunisia are also indicated in the paper [11]; lactation curves of firstborns were characterized by lower daily milk yields than mature cows, but at the same time had higher estimates of the stability index. On the other hand, adult cows reached peak milk yield earlier (within 5-6 weeks of lactation) than first-born cows (within 7-10 weeks of lactation). And the value of the peak milk yield was higher in adult cows (23…34 kg) than in first-born cows (17…20 kg) [11].

CONCLUSIONS

It was established that the number of lactation had a significant effect on all the examined signs of milk productivity of cows (in all cases: $p<0.001$). Age differences in the level of milk productivity were closely related to the shape of the lactation curve of animals; first-borns were characterized by relatively low and stable daily milk yields at all stages of lactation, and after the II-th and III-th calvings, the shape of the lactation curves acquired a typical shape with a rapid increase at the beginning and a gradual decrease in daily milk yields after reaching the peak value.

In most cases, the calendar year of calving probably influenced the quantitative and qualitative characteristics of the milk productivity of the cows of the experimental herd. In general, the animals that calved in 2016 (taking into account the influence of the lactation number) were characterized by the highest estimates of milk productivity in comparison with 2014, 2015 and 2017.

Some trend towards the effect of calving season on milk yield traits was found only among firstborns ($p=0.057$), primarily due to significant differences between the scores of animals that calved in winter and animals that calved in summer or autumn. For the qualitative signs of milk productivity, the influence of the calving season was highly probable and was accompanied by higher estimates of fat and protein content in firstborns calved in the cold seasons of the year (autumn-winter) and low in the warm seasons of the year (spring-summer).

Thus, the obtained results will make it possible to develop breeding programs that will take into account the influence of important paratypic factors on the manifestation of milk productivity of cows of a dairy herd, as well as to increase the accuracy of obtaining estimates of the breeding value of breeders in the conditions of a given farm.

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Вплив номеру лактації, року та сезону отелення на молочну продуктивність корів

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Анотація. Основні ознаки молочної продуктивності голштинської молочної худоби відрізняються в різних країнах через відмінності в місцевості, менеджменті та селекційних цілях. При цьому, прояв не-генетичних (тобто, екологічних) факторів під час виробництва молока, як правило, маскують реальну племінну цінність тварин. Головною метою даного дослідження був аналіз впливу номеру лактації, року та сезону отелення на молочну продуктивність 238 корів голштинської породи протягом 4-річного періоду (2014–2017 рр.). Дослідження було проведено з використанням первинних даних щодо молочної продуктивності худоби в умовах ПрАТ «Племзавод «Степной» Кам'янсько-Дніпровського району Запорізької області. Для кожної тварини були оцінені наступні ознаки: тривалість лактації, надій за 305 днів лактації, надій за всю лактацію, вміст жиру та вміст білка в молоці. Для апроксимації лактаційних кривих в межах кожної субгрупи було використано модель П.Вуда. Всі ознаки молочної продуктивності було проаналізовано на підставі алгоритму одно- чи двофакторного дисперсійного аналізу із фіксованими факторами за допомогою статистичного пакету STATISTICA v. 6.0 (Statsoft Inc.). Було встановлено, що номер лактації вірогідно впливав на всі ознаки молочної продуктивності, що було досліджено (у всіх випадках: $p<0{,}001$). Надій за 305 днів лактації підвищувався зі зростанням номеру лактації. Найвищі значення цієї ознаки було відмічено протягом II-ї та III-ї лактації. Найнижчу оцінку надою за 305 днів лактації корів дійного стада даного господарства було отримано у 2014 році, а найвищу – у 2016 році. Сезон отелення вірогідно впливав на показники молочної продуктивності (насамперед, вміст жиру та білка в молоці) первісток. Крім того, оцінка надою за 305 днів лактації була нижчою серед первісток, які отелились взимку або навесні у порівнянні із тваринами, які отелились восени. Серед повновікових корів впливу сезону отелення не відмічено. Номер лактації та рік отелення вірогідно впливали на оцінки коефіцієнтів та параметрів моделі П. Вуда. Форма лактаційних кривих первісток була більш пласка у порівнянні з повновіковими коровами. Оцінки пікового надою були нижчі, але показник сталості лактаційної кривої був вище під час I-ї лактації. Отже, нами було встановлено, що отримання реальних (незміщених) оцінок ознак молочної продуктивності голштинської худоби потребує попереднього корегування даних щодо впливу номеру лактації, року та сезону отелення

Ключові слова: молочна продуктивність, номер лактації, рік та сезон отелення, модель П. Вуда, молочна худоба