Influence of Growth Retardation of Heifers on the Development, Production, Duration and Efficiency of Productive Lifespan of Dairy Cows

Yuriy Polupan[1], Ruslana Stavetska[2], Yuriy Melnyk[1], Vitaliy Siryak[1]
[1]Institute of Animal Breeding and Genetics nd.a. M. V. Zubets of National Academy of Agrarian Science of Ukraine, 08321, 1 Pogrebniaka str., Chubynske, Boryspil district, Kyiv region, Ukraine
[2]Department of Animal Genetics, Breeding and Selection, Biological-technological Faculty, 09117, Bila Tserkva National Agrarian University, pl. 8/1 Soborna, BilaTserkva, Kyiv region, Ukraine

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Abstract. *It was established that the age at first calving of dairy cows, their milk production, reproductive traits, duration and efficiency of productive lifespan depend on the growth intensity of replacement heifers. Heifers with growth retardation in any period up to 1 year of age are characterized by an older age at first calving (by 4.7–7.9% depending on the age at which growth retardation was observed), lower live weight in the first year of life (by 4.1–24.4%), first lactation milk production (milk yield by 6.1–13.2%, milk fat yield by 7.4–13.1%, milk protein yield by 8.7–17.3%) and lifetime milk production (lifetime milk yield by 12.1–25.9%, milk fat + milk protein yields by 13.1–26.3%), as well as lower milk yield, milk fat and milk protein per one day of life, productive lifetime and lactation (by 8.6–21.1%) compared with animals without growth retardation. Animals with growth retardation are inferior to animals without growth retardation on the investigated traits, even after the subsequent elimination of retardation.*

Introduction

During the second half of the 20th century, significant progress was made in the genetic improvement of dairy cattle due to the selection based on animals' pedigree, production traits, and progeny testing (Brotherstone and Goddard, 2005). In recent years, the emphasis on the assessment of the genetic component has increased not only on the production traits of cows, but also on their growth, exterior, health, fertility, feed conversion efficiency, and survival in the herd (Egger-Danner et al., 2015; Stavetska, 2017), that is, the improvement of dairy cattle increasingly focuses on functional traits (Jenko et al., 2015). Functional traits characterize the milk production efficiency due to the reduction of its cost (Groen et al., 1997) and they are indicators of selection process effectiveness and dairy cattle welfare (De Vries and Marcondes, 2020). Boichard and Brochard (2012) and Fuerst-Waltl et al. (2016) believe that finding a balance between milk production and functional traits will make it possible to extend the lifespan, improve the type and strength of dairy cows.

An important component for creating high-performing dairy herds is targeted growth of replacement heifers. Productive and reproductive performances of dairy cows, their health, longevity and lifetime productivity depend on the quality of young animals (Osten-Sacken, 2005). The cost of raising dairy replacements is quite high and amounts to 15–20% of all expenses on a dairy farm (the first place is taken by cattle feed, and the second place is shared by raising heifers and wages). For example, in the USA, the cost of heifer rearing from their birth to calving is about $2300. Therefore, it is important in a dairy herd to provide the rearing of healthy heifers with optimal growth intensity while simultaneously reducing veterinary costs (Heinrichs, 1993).

The live weight of dairy cattle in the corresponding periods is gaining more and more economic value, as it is related to growth intensity of animals, reflects the conformity of the environmental conditions of the animal body, and determines the value of the carcass after culling and slaughter (Byrne et al., 2016). There is a correlation between the intensity of heifers' growth, their live weight at different age periods and future milk production. In some cases, the value of the correlation coefficient is up to +0.40 (Van Amburgh et al., 1998; James, 2001; Cooke et al., 2013; Polupan et al., 2018). The influence of live weight of heifers on their subsequent milk production is 8.21–42.87% depending on the age and number of lactations, but this relationship is mostly curvilinear (Sieber et al., 1988; Fedorovych, 2004). There is greater reliability between milk yield and live weight of heifers at 1–3 months of age, and it is practically absent at 12 months of age (Zabludovskyi and Golubchuk, 2002).

A direct genetic correlation has also been found between calf birth weight and their weight at first insemination (r = 0.31) (Yin and König, 2018), milk production, reproductive traits (Ghoraishy and

Correspondence to Prof. Dr. YuriyPolupan, Institute of Animal Breeding and Genetics nd.a. M.V. Zubets of National Academy of Agrarian Science of Ukraine, 08321, 1 Pogrebniaka str., Chubynske, Boryspil district, Kyiv region, Ukraine.
E-mail: yupolupan@ukr.net

Rokouei, 2013), as well as an inclination to mastitis and feet disorders (Brotherstone et al., 2007). Therefore, the correlation between live weight of heifers and other traits indicates the possibility of its use for early indirect selection to improve economically useful traits of cows.

The importance of raising dairy replacement heifers is confirmed by studies conducted in Australia. It has been established that heifers that reach the target live weight faster (85% of the average mature cow weight) are characterized by better development of reproductive organs. That is why they are mated earlier. These heifers dominate by live weight at first calving, milk production and productive lifetime. Primiparous cows with a 50 kg higher live weight had a higher milk yield by 1041 kg, milk fat yield by 38.5 kg, and milk protein by 42.5 kg over the first three lactations (Beggs and Jagoe, 2013).

Brickell et al. (2009) have reported that 14.5% of live-born dairy heifers did not remain in the herd until the first lactation; on average, 6.8% of heifers died or they were culled during the first six months of life. This causes significant losses for milk producers. Recently, Hyde et al. (2020) have found that mortality of dairy calves in the UK in the first three months of life is 6%, and that this rate has not changed much since the 1990s. Thus, over the last 30 years, this question has remained relevant.

Effective rearing of replacement heifers is determined by the compliance of their live weight with the breed standard in a definite age. However, in practice, some animals may lag behind in growth during the rearing period for various reasons like morbidity, insufficient or substandard feeding, violation of technology, etc. Genetic factors should not be excluded from this list. In the future, biological mechanisms of compensatory growth can contribute to the achievement of normal development of animals before the beginning of their reproductive and productive use (Busenko and Golub, 2010; Karapuz and Karapuz, 2010; Klimkovetskyi et al., 2020). However, according to the Chirvinsky-Maligonov law, during the period of growth retardation, the internal organs that develop most intensively during this period may suffer. Compensation for growth retardation may be incomplete and does not allow realizing the genetic potential for performance (Chirvinsky, 1949; Maligonov, 1968; Pelykh and Levchenko, 2012; Polupan, 2016; Klimkovetskyi et al., 2020). Thus, in the research of Klimkovetskyiet al. (2020), it has been established that growth retardation of heifers at an early age is compensated for more slowly. Under the conditions of live weight compensation before the beginning of reproductive use, growth retardation does not affect the milk production of primiparous cows, but productive lifetime and lifetime production of cows decrease (Klimkovetskyi et al., 2020).

This study aimed to investigate the effect of replacement heifers' growth retardation from birth to 12 months of age on their growth, performance, duration and efficiency of productive lifespan.

Material and methods

The research was conducted in a retrospective statistical experiment in the herd of Ukrainian Black-and-White Dairy and Holstein breeds in Breeding Station Terezyne, which is located in Kyiv region, Ukraine. The materials from electronic database Dairy Management System ORSEK were used. In total, 930 cows from their birth to culling were included in the study. To evaluate growth, milk and reproductive traits, duration and efficiency of productive lifespan, five groups were formed: control (without growth retardation) and four experimental groups with growth retardation at the age of 0–3, 3–6, 6–9 and 9–12 months. Growth retardation of heifers was considered to be less than 500 g of average daily gain for the corresponding three-month period.

Animal growth was studied by their live weight (kg) at the age of 6, 12 and 18 months of age and average daily gain (g) from birth to the age of 1.5 years; milk production – 305-day first and second lactations milk yield (kg), milk fat concentration (%) and yield (kg), milk protein concentration (%) and yield (kg); reproductive traits – age at first calving (days), calving-conception interval (days), reproductive capacity coefficient (%),which is defined as a number of days per year (365) divided by calving interval.

A retrospective analysis of duration and efficiency of productive lifespan of cows was carried out according to our methodology (Polupan, 2010, 2014). In particular, lifespan, productive lifetime, total lactation length (days), lifetime number of lactation, lifetime milk yield, fat yield and protein yield (kg), lifetime, productive life and total lactation daily milk yield (kg), daily milkfat and daily milk protein yields (g) of cows were studied.

The calculations were performed by methods of parametric statistics (Osadcha and Shanaieva-Tsymbal, 2022) with the software package Statistica 12.0 (Fetisov, 2018). The investigated characteristics in the groups were estimated by calculating the arithmetic means ($\overline{x}$) and their standard errors (± S.E.). The level of statistical significance of the difference in group means ($d = \overline{x}_2 - \overline{x}_1$) was determined by calculating the reliability criterion Student $t_d = \frac{d}{S.E._d} = \frac{(\overline{x}_2 - \overline{x}_1)}{\sqrt[2]{S.E._1^2 + S.E._2^2}}$ by its further comparison with standard values. The reliability of the results was compared with three standard levels of statistical significance with their designation $P < 0.05$, $P < 0.01$, $P < 0.001$.

Results

By comparing the means between the groups, it was established that heifers of all experimental groups had lower live weight at 6, 12, and 18 months of age compared with heifers of the control group (Table 1).

Table 1. Growth and reproductive traits of cows with growth retardation in different rearing periods (Mean ± S.E.)

Parameters 0–3		Groups with growth retardation in period, *age interval in months*				Group without growth retardation (control)
		3–6	6–9	9–12		
Number of cows		48	47	60	72	930
Live weight *(kg)* at the age, *months*	6	135 ± 1.5[c]	127 ± 1.4[c]	154 ± 2.4[c]	166 ± 2.3	168 ± 0.5
	12	261 ± 2.8[c]	259 ± 3.1[c]	252 ± 2.9[c]	267 ± 3.0[c]	288 ± 0.6
	18	371 ± 6.3[2]	376 ± 4.6[b]	375 ± 2.9[c]	370 ± 3.5[c]	392 ± 0.9
Average daily gain *(g)* at the age, *months*	0–3	451 ± 6.4[c]	589 ± 10.4[c]	652 ± 16.0[c]	702 ± 15.1	726 ± 3.1
	3–6	647 ± 15.4[c]	423 ± 9.2[c]	650 ± 13.9[c]	725 ± 12.2	707 ± 2.6
	6–9	666 ± 16.6	693 ± 23.2	410 ± 9.5[c]	674 ± 10.8	682 ± 2.6
	9–12	722 ± 19.1[c]	755 ± 19.5[c]	661 ± 13.9	435 ± 8.6[c]	640 ± 3.0
	0–12	622 ± 7.7[c]	615 ± 8.7[c]	593 ± 7.8[c.]	634 ± 8.0[c]	689 ± 1.7
	12–18	631 ± 24.6[a]	670 ± 25.3[c]	667 ± 15.6[c]	562 ± 15.3	569 ± 3.5
Age at first calving, *days*		865 ± 12.2[b]	872 ± 10.0[c]	891 ± 14.0[c]	877 ± 15.4[c]	826 ± 3.8
Calving-conception interval, *days*		150 ± 14.0[a]	141 ± 17.9[a]	180 ± 20.6	169 ± 19.4	181 ± 4.9
Reproductive capacity coefficient		0.887 ± 0.026	0.916 ± 0.027[a]	0.857 ± 0.029	0.871 ± 0.024	.847 ± 0.007

Note: as compared with control group [a] – $P < 0.05$; [b] – $P < 0.01$; [c] – $P < 0.001$.

In particular, the live weight of heifers with growth retardation at 0–3 months was lower compared with the control group by 21–33 kg or 5.4–19.7%, at 3–6 months by 16–41 kg or 4.1–24.5%, at 6–9 months by 14–36 kg or 4.4–12.5%, at 9–12 months by 2–21 kg or 5.4–7.3% (in all cases $P < 0.001$ or $P < 0.01$).

The average daily gain of heifers with growth retardation was lowest compared with the control group during the retardation period. Heifers with growth retardation from birth to 3 months had lower average daily gain in this period compared with the control group by 275 g or 37.9%, at 3–6 months by 284 g or 40.2%, at 6–9 months by 272 g or 39.9%, and at 9–12 months by 205 g or 32.0%. In all cases at the highest level of statistical significance of the reliability, the difference in means was observed. Despite a rather high average daily gain of heifers in other corresponding periods, which in many cases exceeded the average daily gain in the control group, the mechanisms of compensatory growth did not ensure the achievement of its level in the first year of postnatal growth, as in the analogue in the control group. Heifers of the experimental groups were inferior to the animals of the control group in average daily gain from birth to one year of age by 55–96 g or by 8.0–13.9%. Significantly higher growth intensity of heifers of most experimental groups after one year of age also did not provide full compensation of growth retardation to 18 months of age.

Heifers of breeding age with growth retardation in different periods of the first year of postnatal growth were characterized by a slightly older age at first calving (by 39–65 days) compared with animals of the control group ($P < 0.001$ or $P < 0.01$). At the same time, the primiparous cows in experimental groups had a shorter calving-conception interval (by 1–40 days) and, as a result, a higher reproductive capacity coefficient (by 0.010–0.069).

Despite the older calving, the primiparous cows of experimental groups with growth retardation in different rearing periods showed less 305-day milk yield and milk fat and protein yields compared with the control group (Table 2).

The greatest decrease of milk production was noted for groups with growth retardation after weaning and attaining puberty phases. In the group with growth retardation in the period of 3–6 months, the decrease in milk yield compared with the control group was 880 ± 206.6 kg or 13.2% ($t_d = 4.26$, $P < 0.001$); at 6–9 months, it was 557 ± 163.6 kg or 8.4% ($t_d = 3.40$, $P < 0.001$). Milk fat yield was lower respectively by 32.7 ± 7.80 kg or 13.1% ($t_d = 4.19$, $P < 0.001$) and 22.1 ± 6.27 kg or 8.9% ($t_d = 3.52$, $P < 0.001$), milk protein yield by 37.7 ± 6.78 kg or by 17.3% ($t_d = 5.56$, $P < 0.001$) and 24.8 ± 5.85 kg or by 11.4% ($t_d = 4.24$, $P < 0.001$). Milk protein concentration in the groups with growth retardation was lower by 0.06–0.16% ($P < 0.001$) than in the control group.

As a result, the negative effect of growth retardation during different periods of the first year of postnatal growth does not reveal a prolonged effect on 305-day second lactation. Second lactation cows with growth retardation in the periods of 0–3 and 3–6 months were characterized by even slightly higher milk yield compared with the control group (+46–224 kg). The only exception was cows with growth retardation in 9–12 months, which had significantly lower milk yield (by 664 ± 230.4 kg, $t_d = 2.88$, $P < 0.01$), milk fat yield (by 25.9 ± 8,82 kg, $t_d = 2.94$, $P < 0.01$) and milk protein yield (by 25.7 ± 7.77 kg, $t_d = 3.31$, $P < 0.001$).

At the same time, growth retardations in different periods of the first year of heifer rearing have a prolonged effect on the efficiency of productive lifespan of cows (Table 3).

Table 2. Milk production of cows with growth retardation in different rearing periods (Mean ± S.E.)

Parameters 0–3 3–6			Groups with growth retardation in period, *age interval in months*				Group without growth retardation (control)
			6–9	9–12			
Number of cows			48	47	60	72	930
First lactation	milk yield, *kg*		6237 ± 198.9	5762 ± 200.8^{c}	6085 ± 156.2^{c}	6178 ± 163.8^{b}	6642 ± 48.6
	milk fat	%	3.69 ± 0.012^{c}	3.75 ± 0.014	3.72 ± 0.013	3.72 ± 0.009^{b}	3.74 ± 0.003
		kg	230.2 ± 7.49^{a}	216.0 ± 7.57^{c}	226.6 ± 5.98^{c}	230.2 ± 6.14^{b}	248.7 ± 1.87
	milk protein	%	3.13 ± 0.012^{c}	3.15 ± 0.012^{c}	3.17 ± 0.016^{c}	3.23 ± 0.013^{c}	3.29 ± 0.003
		kg	195.6 ± 6.47^{c}	180.8 ± 6.58^{c}	193.7 ± 5.61^{c}	199.5 ± 5.56^{b}	218.5 ± 1.65
Second lactation	milk yield, *kg*		7386 ± 290.9	7208 ± 308.3	7020 ± 350.7	6498 ± 221.2^{b}	7162 ± 64.3
	milk fat yield, *kg*		269.8 ± 10.85	266.7 ± 12.09	261.5 ± 13.51	243.9 ± 8.46^{b}	269.8 ± 2.49
	milk protein yield, *kg*		232.9 ± 9.50	227.1 ± 10.21	226.7 ± 11.59	211.2 ± 7.45^{c}	236.9 ± 2.19

Note: as compared with the control group ^{a} – $P < 0.05$; ^{b} – $P < 0.01$; ^{c} – $P < 0.001$.

Table 3. Duration and efficiency of productive lifespan of cows with growth retardation in different rearing periods (Mean ± S.E.)

Parameters 0–3		Groups with growth retardation in period, *age interval in months*				Group without growth retardation (control)
		3–6	6–9	9–12		
Number of cows		48	47	60	72	930
Duration, *days*	lifespan	2012 ± 113.7	1913 ± 86.9	1945 ± 64.0	2116 ± 79.5	2064 ± 21.3
	productive lifetime	1147 ± 114.9	1041 ± 87.8^{a}	1054 ± 66.8^{b}	1239 ± 83.2	1243 ± 21.9
	total lactation	1008 ± 96.3	934 ± 78.4^{a}	932 ± 57.7^{b}	1091 ± 71.6	1108 ± 18.7
Lifetime number of lactation		3.06 ± 0.259	2.70 ± 0.187	2.72 ± 0.167	3.14 ± 0.210	3.04 ± 0.054
Lifetime production, *kg*	milk yield	18 592±2025.4	16 698±1603.1^{b}	16 191±1125.7^{c}	19 191±1397.3	21 840±340.0
	milk fat yield	685 ± 76.4	619 ± 59.8^{b}	602 ± 42.3^{c}	717 ± 52.3	821 ± 15.1
	milk protein yield	592 ± 68.0	531 ± 52.8^{c}	526 ± 37.9^{c}	626 ± 46.4^{a}	723 ± 13.3
	milk fat + protein yields	1277 ± 144.3	1150 ± 112.6^{b}	1139 ± 81.0^{c}	1343 ± 98.7	1545 ± 28.3
Daily milk yield per cow, *kg*	lifespan	8.3 ± 0.45^{b}	8.1 ± 0.48^{c}	7.9 ± 0.36^{c}	8.5 ± 0.36^{c}	9.9 ± 0.11
	productive lifetime	16.2 ± 0.67^{a}	15.8 ± 0.68^{b}	15.7 ± 0.53^{c}	15.8 ± 0.55^{c}	17.8 ± 0.15
	total lactation	18.0 ± 0.68^{a}	17.5 ± 0.72^{b}	17.5 ± 0.54^{c}	17.6 ± 0.53^{c}	19.7 ± 0.15
Daily milk fat and protein yields per cow, *g*	lifespan	569 ± 32.2^{c}	554 ± 33.5^{c}	553 ± 26.2^{c}	591 ± 25.2^{c}	701 ± 7.6
	productive lifetime	1103 ± 45.9^{b}	1084 ± 46.7^{c}	1090 ± 38.4^{c}	1102 ± 38.8^{c}	1262 ± 10.7
	total lactation	1230 ± 46.8^{b}	1199 ± 49.9^{c}	1217 ± 39.2^{c}	1225 ± 37.5^{c}	1394 ± 11.0

Note: as compared with the control group ^{a} – $P < 0.05$; ^{b} – $P < 0.01$; ^{c} – $P < 0.001$.

The most significant decrease in the duration of lifespan, productive lifetime and total lactation, as well as lifetime number of lactation was noted in groups with low average daily gains in the period from 3 to 9 months. In particular, cows with growth retardation at the age of 3–6 months compared with the control group had a lower lifetime number of lactation by 0.34 ± 0.195 (t_d = 1.74, $P < 0.1$), and at 6–9 months by 0.32 ± 0.176 (t_d = 1.82, $P < 0.1$). In the duration of a lifespan, this difference was 151 ± 89.5 (t_d = 1.69, $P < 0.1$) and 119 ± 70.3 (t_d = 1.69, $P < 0.1$) days, respectively; in the duration of a productive lifetime, this difference was 202 ± 90.5 (t_d = 2.23, $P < 0.05$) and 189 ± 70.3 (td = 2.69, $P < 0.01$) days; in the duration of a total lactation duration, this difference was 174 ± 80.6 (t_d = 2.16, $P < 0.05$) and 176 ± 60.7 (t_d = 2.90, $P < 0.01$) days.

In all experimental groups with growth retardation, a decrease of lifelong milk production indicators was noted. The highest losses in milk production were noticed for groups with growth retardation at 3–9 months of age. Cows with low average daily gains at the age of 3–6 months compared with the control group had less lifetime milk yield by 5142 ± 1638.8 kg (t_d = 3.14, $P < 0.01$), and at 6–9 months by 5649 ± 1175.9 kg (t_d = 4.80, $P < 0.001$), and lifetime milk fat + protein yields by respectively by 395 ± 116.1 kg (t_d = 3.40, $P < 0.001$) and 406 ± 85.8 kg (t_d = 4.73, $P < 0.001$). Losses in daily milk fat and protein yields per cow with growth retardation at 0–3 months of age were 132 ± 33.1 g (t_d = 3.99, $P < 0.001$), at 3–6 months – 147 ± 34.4 g (t_d = 4.27, $P < 0.001$), at 6–9 months – 148 ± 27.3 g (t_d = 5.42, $P < 0.001$), and at 9–12 months of age – 110 ± 26.3 g (t_d = 4.18, $P < 0.001$). Therefore, the growth retardation of heifers at all periods of the first year of postnatal growth causes a significant decrease in the efficiency of a productive lifespan. More significant losses of milk production were observed due to reduced average daily gains after the milk feeding and attaining puberty phases (up to 9 months of age).

Discussion

Literary sources report on the causes that lead to calves' growth retardation and ways to eliminate them. The intensity of calves' growth reflects the compliance of feeding with the needs of the animal's body. If animals were fed unbalanced diets, were not supplied with nutrient needs and suffered from stress or diseases, growth retardation was usually observed (Roland et al., 2016; Shivley et al., 2018). Growth retardation has also been associated with underfeeding during the milk feeding phase, according to the long-established industry standard to restrict milk feeding of calves (Khan et al., 2007; Palczynski et al., 2020), low intake of concentrates by calves at the weaning, regrouping calves more than twice before weaning and a low incidence risk of milk fever (< 5%) (Tautenhahn et al., 2020). A high rate of calf morbidity and, as a result, growth retardation are associated with increasing use of antibiotics and a noticeable increase in antimicrobial resistance (World Health Organization, 2014). Costa et al. (2019) believe that under industrial intensive technology, improving animal welfare, in particular keeping calves in pairs or groups, rather than individually, increasing the amount of milk in the milking phase of rearing to avoid suffering calves from hunger, and using local anesthesia during dehorning would help reduce growth retardation of calves.

Wathes et al. (2014) believed that optimal average daily gain of dairy replacement heifers during the rearing period was 750 g. Soberon et al. (2012) reported it to be 660–820 g, Van Amburgh et al. (1998) found that it was 400–800 g before puberty, while Lytvynenko (2010) and Poslavska et al. (2016) recorded 650–700 g during the entire rearing period, including700–800 g at the age of 0–6 months, 600–700 g at 6–12 months, and 550–600 g at 12–24 months. If average daily gain is lower, heifers reach puberty and age at first calving later (Sumner and Keyserlingk, 2018). The current study found that the average daily gain of heifers in the control group was 716 g up to 6 months of age, 661 g at the age of 6–12 months, and 560 g at 12–18 months. This result is in line with what has been described by Van Amburgh et al. (1998), Lytvynenko (2010) and Poslavska et al. (2016). The average daily gain of heifers with growth retardation was lower by 32.5–40.2%, depending on the age of the calves.

The optimal age at first calving in dairy cattle varies from 23 to 25 months (Do et al., 2013; Wathes et al., 2014). Cook et al. (2013) and Wathes et al. (2014) called the target age at first calving for dairy cattle to be 24 months. Under these conditions, optimal economic efficiency in dairy farming can be achieved due to high lifetime fertility of cows, high survival rates, and high milk production, compared with heifers with an older age at first calving. At the same time, Kalińska et al. (2019), Haworth et al. (2008) and Frejlach et al. (2015) reported that the highest first lactation yield, lifetime milk yield, lifetime milk fat and milk protein yields were produced by cows between 24 and 28 months of age at first calving and even later. The age of cows at the first calving in the current study in the control group was within these limits – 27 months. Cows of all groups with growth retardation during the rearing period were 28–29 months at the age at first calving. The oldest age at first calving observed in cows with growth retardation was 6–9 months, that is, during the period of intensive puberty.

Rational rearing of replacement heifers is an important factor that determines the subsequent milk production of cows. Numerous studies have established the dependence of milk production on live weight of animals during their rearing period (Bazeley et al., 2016; Bondarchuk, 2016; Heinrichs et al., 2017). According to Shuliar et al. (2020), in the herd of the Ukrainian Black-and-White dairy breed, newborn heifers with 32–33 kg of live weight,166–175 kg at the age of 6 months, 281–290 kg at 12 months, and 381–390 kg at 18 months were characterized by higher milk production (milk yield, milk fat and protein yields, and their total amount). Similar results were obtained in our study in the control group.

Prishedko et al. (2017) have reported that higher milk production was associated with higher average daily gain. According to the results of the current study, Holstein cows with a higher average daily gain up to 18 months of age prevailed in 305-day first lactation milk yield by 1093.0 kg (28.06%, $P < 0.001$), and milk fat yield by 40.60 kg (28.93%, $P < 0.001$). It is obvious that animals in the control group and with an earlier age at first calving (27

months in the current study) were characterized by higher milk production. It was established that 305-day first lactation milk yield in the groups of cows with growth retardation, compared with the control group, was lower on average by 576 kg (8.6%), milk fat yield by 23.0 kg, and milk protein yield by 26.1 kg. The milk protein concentration in groups with growth retardation was lower compared with control by 0.06–0.16%. It was in line with a statement of Van Amburgh et al. (1998), who noted that milk yield of primiparous cows with low average daily gain during the rearing period was lower by 10–40%.

Earlier in our research, it was found that duration and efficiency of a productive lifespan of cows depends on growth intensity of heifers (Siryak et al., 2021). In particular, it was established that the highest duration and efficiency of a productive lifespan was observed in cows with live weight at the age of 6 months higher than 160 kg with an average daily gain up to 6 months above 700 g. In this study, live weight and average daily gain within these limits were found in cows in the control group and with growth retardation at the age of 9–12 months. Cows of these groups had a higher productive lifetime by 94–200 days, lifetime milk yield by 1923–4324 kg, lifetime milk fat yield by 84–194 kg, lifetime milk protein yield by 82–148 kg, and lifetime milk fat + protein yields by 167–305 kg.

Consequently, growth retardation of heifers had a negative effect on their rearing efficiency, reproductive traits, milk production and lifetime efficiency. The exceptional importance of the period from birth to 9 months of age in dairy heifers rearing was highlighted. This is in line with research results of Klimkovetskyi et al. (2020).

Conclusions

It was established that growth retardation of heifers in different periods from birth to 12 months of age had irreversible effects on productive traits of cows. Lower growth intensity, milk and reproductive performance were found in groups with growth retardation from birth to 9 months of age, that is, during milk feeding and attaining puberty phases. Cows with growth retardation were characterized by lower live weight at the age of 1 year (on average by 28 kg) and 1.5 years (by 19 kg), older age at first calving (by 50 days), lower first lactation milk yield (by 576.5 kg), milk fat yield (by 22.9 kg) and milk protein yield (by 26.1 kg), as well as lower lifetime milk yield (by 4172 kg), lifetime milk fat yield (by 165 kg), lifetime milk protein yield (by 154 kg) and milk fat and milk protein per one day of life (by 134 g), productive lifetime (by 167 g) and lactation (by 176 g) compared with the control group.

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