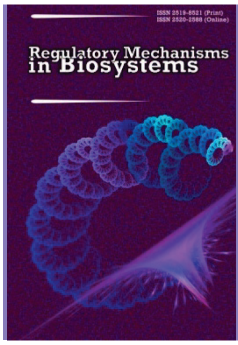

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Influence of growth intensity of black and white dairy cattle on their reproduction and productivity under free housing

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Targeted and economically justified livestock breeding, considering the biological characteristics of growing animals, is a key issue in dairy farming. One of the insufficiently studied aspects of livestock breeding is the period of animal development from the first insemination to the first lactation, which affects their safety, productivity, and reproductive capacity. The study was conducted at the breeding station of the Ukrainian black-and-white dairy breed of the state enterprise "Kutuzivka" in Kharkiv district, Kharkiv region, Ukraine. Animals born in different years differed in growth intensity, reproductive performance, and productivity. At the same time, there was a tendency for the milk yield of first-born heifers to improve with an increase in live weight gain from insemination to the first lactation. According to the results of the correlation analysis, this weight gain had a significant relationship with age and live weight at first insemination, milk yield for 90 days, milk yield for 150 days, milk yield for 305 days of lactation, and live weight at first lactation. The survival rate of all first-born heifers with a weight gain of more than 146 kg was 16–21% higher compared to animals with a lower weight gain. Also, such animals had the highest milk yields for all lactation periods. Their advantage in milk yield was 234 kg for the first 90 days of lactation, 331–381 kg for 150 days of lactation, and 573–675 kg for 305 days of lactation. Groups of animals with different live weight gain after the first insemination also had significant differences in the duration of the service period and the number of stillborn calves. The results of the study concluded that the animals with the highest gain were significantly younger and had a higher live weight at insemination as well as the highest live weight in the first lactation. The early maturation of replacement heifers will contribute to the intensive reproduction of the herd, which will increase the profitability of the dairy industry. Further research is needed to determine the effect of growth intensity on the reproductive performance of second and subsequent lactation cows and calf safety.

Keywords: heifers; cows; body weight; lactation; stayability; productivity; pregnancy; reproduction.

Introduction

The success of creating a highly productive herd depends on many factors, including the level of rearing of replacement stock (Nanka et al., 2018; Tschopp et al., 2021). The reproductive efficiency of dairy heifers is crucial for the economics of enterprises, as reducing the age of first insemination minimizes the cost of raising them (Heinrichs et al., 2013; Silva et al., 2015). Irish researchers estimated the cost of raising a dairy heifer to calving at the age of two years at €1,500 (Shalloo et al., 2014), American researchers at $1,803 (from birth to calving) (Heinrichs et al., 2013), and Dutch researchers at €1,423 to €1,715 (Mohd et al., 2012). The rearing period is unproductive from a financial standpoint, and its length directly affects the total cost of rearing and the time it takes for an individual heifer to recoup these costs (Hawkins et al., 2020). English researchers have suggested that all the costs associated with raising heifers are usually recouped when they reach 1.5–2.0 lactations (Boulton et al., 2017). However, only about 55% of dairy heifers reach the third lactation (Brickell & Wathes, 2011). One key factor influencing the growth of dairy heifers is the body weight of a mature cow (Busanello et al., 2022). Economic analysis has demonstrated that larger, well-grown heifers are more profitable due to their enhanced productive potential, all other factors being equal. Archbold et al. (2012) found a correlation between body weight at mating and subsequent calving date, live weight of the cow, milk fat, and protein yield. Previous studies have demonstrated a positive correlation between pre-calving body weight and milk production in the first lactation (McNaughton & Lopdell, 2013; Eetvelde et al., 2017). These findings support the conclusion that higher productivity during the first and second lactations can be achieved by raising heifers to a higher body weight. New Zealand scientists have identified the potential for increased milk production in the first lactation of dairy heifers by increasing heifer body weight and the advantage for greater milk production of a balanced feeding regime for lighter heifers to achieve higher body weight before calving (Handcock et al., 2019; Martín et al., 2020). Other studies have demonstrated a positive correlation between the live weight of replacement heifers and their reproductive performance and resilience to adverse factors (Handcock et al., 2020).

One of the primary objectives of dairy farmers is to improve the health and longevity of their animals. However, there has been limited research into the genetic components of heifer survival. Studies have found that 7.9% of calves in the UK were born dead or died within the first 24 hours of life, and another 3.4% of heifers within the first 28 days of life (Brickell et al., 2009). Calf and heifer mortality have a significant economic impact, not only in terms of the value of the animals but also in terms of the loss of genetic gain that accumulates over subsequent generations (Henderson et al., 2011) and the opportunity cost of resource use (Ventura et al., 2021). Replacement heifers represent the farm's future, and herd management is an important factor in the sustainability of the farm and the dairy industry as a whole (Aseged et al., 2023). Management decisions regarding feeding, housing, disease control, and breeding affect the growth and development of animals (Zipp & Knierim, 2020; Freetly et al., 2021). This, in turn, affects the age of conception and the age of first calving, which can have long-term economic consequences (Cooke et al., 2013).

Over the past few decades, advances in general management, feeding, health, and breeding have led to significant increases in cow productivity (Holger, 2023). Various studies have found that the beginning of lactation was followed by a rapid increase in milk production during early lactation, while live weight and body condition declined slightly (Köck et al., 2018; Mäntysaari et al., 2019). This pattern reflects the energy status of animals. During early lactation, most animals enter a negative energy balance state, mobilizing missing nutrients from body reserves (Collard et al., 2000). Later in lactation, when milk production slowly decreases, feed intake remains constant. This results in a positive energy balance, enabling animals to begin accumulating new body reserves. The relationship between negative energy balance, fertility, and metabolic diseases has been well-documented in numerous studies (Esposito et al., 2014; Pérez-Báez et al., 2019). Cows with a severe negative energy balance are more susceptible to oxidative stress, metabolic disorders, and impaired fertility (Ducháček et al., 2020; Młynek et al., 2022). A study conducted by Brazilian researchers revealed that cows with low and medium body weight loss (less than 60 kg of body weight change) exhibited a higher probability of achieving adequate reproduction than cows with high body weight loss (more than 60 kg of body weight). The findings showed that 45.5% and 45.8% of cows with low and medium body weight loss, respectively, were able to reproduce adequately, while only 24.4% of cows with high body weight loss were able to do so. Improving the fertility of dairy cows should be achieved by minimizing the loss of live weight at the beginning of lactation (Poncheki et al., 2015). It is still important to consider breeding against post-calving weight loss (i.e., in favor of rapid adaptation to feed intake), as this can be more effective than breeding for antagonistic traits. The genetic correlations between weight loss between one and five weeks after calving and daily milk yield ranged from –0.26 to 0.05 in first-calf cows and from –0.11 to 0.10 in second-lactation cows. Despite a positive correlation between mobilization (as measured by weight loss) and milk production in the early stages of lactation, the same mobilization was genetically independent of milk production in mid- or late-lactation after the negative energy balance was resolved (Tribout et al., 2023). This allows any unwanted correlation to be broken.

Therefore, studying the effect of dairy cattle growth intensity on their reproductive capacity, stayability, and milk production is an urgent issue of dairy cattle technology.

Materials and methods

The work was carried out by the data of zootechnical accounting of animals at the breeding plant for the Ukrainian black-and-white dairy breed SE RF "Kutuzivka" in Kharkiv district, Kharkiv region of Ukraine. A total of 3,519 heifers were analyzed, with the following distribution by year of birth: 2013 (668 head), 2014 (776 head), 2015 (595 head), 2016 (808 head), and 2017 (672 head).

At the dairy complex of SE RF "Kutuzivka", the animals are kept free-range on long-lasting straw bedding. The cows are milked in the parlor using the Yalynka milking machine. The animals' diet consists of fodder mixtures starting from the age of 3 months. The yield per cow during this period is over 6,000 kg of milk.

The calculations were based on data from the farm's zootechnical and breeding records. The live weight of heifers was recalculated for the exact age in months and the date of fertile insemination. The live weight of cows was determined in the period from calving to 150 days of lactation. The data were obtained by weighing cows when they were transferred from the newborn group to the main herd group. The transfer period exhibited notable variability, ranging from 30 to 150 days. This was since cows experiencing complications post-calving were only transferred once they had recovered.

At the outset of the research, the impact of the year of birth of heifers on their growth, reproductive capacity, safety, and subsequent milk production was evaluated. These indicators were also compared with those of animals that had left the herd during the experimental period.

At the second stage, the impact of weight gain from the first insemination to the first lactation was evaluated. All animals were grouped into three categories based on this indicator. The first group included the firstborn with a weight gain of up to 56 kg, the second – 56–146 kg, and the third – above 146 kg.

The results were analyzed using a set of generally accepted methods, including a systematic review (introduction and discussion), generalization (interpretation of results), and zootechnical (assessment of productivity, reproduction, and safety).

The mean (x) ± standard deviation (SD) was calculated for the data. A one-factor analysis of variance was performed to determine the significance of differences between the groups. The strength of influence of the factors was calculated as the ratio of the intergroup variance to the total variance, expressed as a percentage. The probability of differences between individual groups was determined by the posteriori Tukey test. A Pearson's test was employed to assess the likelihood of calf mortality, abortion, and animal survival. All calculations were conducted using the SPSS-20.0 computer program.

Results

The growth dynamics of heifers of different years of birth, as determined by the results of the analysis of variance, exhibited significant ($P < 0.05$) differences from birth to 24 months of age. The maximum and minimum average live weights at birth were 3.1 and 26.6 kg, respectively, while the maximum and minimum average live weights at 6 months of age were 26.6 and 60.7 kg, respectively. The maximum differences in live weight of heifers were established at the age of 20 months – 126.1 kg. Thereafter, the differences decreased, and at the age of 24 months, they amounted to 50.2 kg. The impact of the factor "year of birth" on the live weight of heifers increased from birth to 19 months of age from 8.0% to 43.2%, then decreased, and at 24 months of age was equal to 9.5%. Heifers born in 2013 exhibited the lowest growth intensity, while those born in 2017 exhibited the highest. This indicates that the growth intensity of the experimental heifers underwent a significant change during the experimental period (Table 1).

It should be noted that the growth rate of heifers that survived to 24 months of age was significantly higher than the average growth rate of animals that left the herd during this period (Table 2).

The average live weight at birth was 2.0 kg, at 6 months of age it was 7.4 kg, and at 12 months it was 24.1 kg. The maximum differences in the live weight of heifers were found at the age of 21 months, at 45.2 kg, then they decreased and at the age of 24 months, they were equal to only 17.3 kg. Consequently, the impact of stayability to the first calving on the live weight of heifers was less pronounced than the previous factor. Variations ranging from 1.2% to 7.5% were observed at different ages. The slower growth rate of heifers that left the herd before the first calving can be attributed to the fact that, in most cases, heifers that are stunted due to diseases are culled.

The stayability of heifers up to 18 months of age on the farm is quite low. It ranged from 73.2% in heifers born in 2015–2017 to 77.6% in animals born in 2014. The maximum difference in the stayability of heifers up to this age was 6.3% and was not significant ($P > 0.05$). The dynamics of changes in the safety of heifers of different ages varied. The differences between the maximum and minimum values in the stayability up to 3 months of age were 9.7%, up to 6 months – 13.2% ($P < 0.05$), up to 9 months – 12.0%, and up to one year of age – 7.1% (Table 3).

All fertilized heifers survived to the first calving, although the level of stayability to fertile insemination in animals born in different years did not differ significantly (7.0%, $P > 0.05$). The survival of the firstborns until the second calving differed with the same probability level. The difference between the maximum and minimum values of animal stayability by day 90 of the first lactation was 9.2%, by day 150 – 9.8%, and by the second calving – 8.3% and was also unreliable (Table 4). The birth year of heifers significantly influenced the age of their first insemination ($\eta^2 = 25.7\%$, $P < 0.001$). The maximum difference between the mean values in the groups by this indicator was more than 4 months (Table 5).

Table 1
Growth dynamics of heifers depending on the year of birth (kg)

Age, months	Year of birth									
	2013		2014		2015		2016		2017	
	n	x ± SD	n	x ± SD	n	x ± SD	n	x ± SD	n	x ± SD
0	668	32.7 ± 4.1^{a}	776	32.5 ± 4.1^{a}	595	33.3 ± 3.4^{a}	808	30.6 ± 4.2^{b}	672	30.2 ± 4.2^{b}
1	609	46.0 ± 5.7^{b}	732	48.4 ± 6.4^{a}	552	48.3 ± 5.7^{a}	722	45.2 ± 6.6^{b}	646	43.7 ± 6.6^{c}
2	608	62.7 ± 7.1^{c}	711	64.4 ± 6.9^{abc}	543	65.2 ± 7.4^{a}	699	63.3 ± 7.6^{c}	633	63.5 ± 7.5^{bc}
3	591	83.3 ± 8.7^{b}	675	81.3 ± 9.9^{c}	500	83.5 ± 10.2^{b}	657	84.2 ± 10.4^{b}	604	86.7 ± 9.9^{a}
4	590	105.4 ± 12.0^{b}	653	100.5 ± 13.2^{c}	470	101.0 ± 13.5^{c}	649	105.0 ± 13.7^{b}	611	112.5 ± 13.3^{a}
5	572	126.3 ± 15.1^{b}	643	119.6 ± 16.4^{c}	462	117.6 ± 18.1^{c}	630	124.2 ± 17.1^{b}	607	139.4 ± 18.1^{a}
6	569	143.0 ± 18.2^{b}	626	136.7 ± 20.6^{c}	455	134.7 ± 21.5^{c}	617	140.6 ± 19.5^{b}	605	161.3 ± 21.9^{a}
7	569	158.1 ± 20.5^{b}	640	154.4 ± 25.4^{b}	455	151.9 ± 24.6^{c}	623	156.4 ± 22.2^{b}	598	182.8 ± 26.3^{a}
8	556	175.1 ± 22.0^{b}	626	173.7 ± 28.8^{bc}	446	169.1 ± 28.1^{c}	603	173.6 ± 26.1^{b}	589	205.5 ± 30.6^{a}
9	558	192.1 ± 24.8^{b}	630	190.7 ± 32.1^{bc}	450	186.1 ± 33.0^{c}	618	192.6 ± 30.8^{b}	585	227.2 ± 36.1^{a}
10	545	210.3 ± 28.9^{b}	618	208.6 ± 36.1^{bc}	444	206.1 ± 36.9^{c}	600	214.1 ± 35.3^{b}	572	252.6 ± 42.1^{a}
11	537	229.6 ± 31.8^{b}	616	228.3 ± 39.7^{bc}	438	227.4 ± 39.4^{c}	590	234.4 ± 38.1^{b}	559	279.8 ± 46.1^{a}
12	541	248.9 ± 36.1^{c}	625	249.6 ± 42.6^{c}	446	249.9 ± 40.4^{c}	613	257.8 ± 40.9^{b}	551	310.6 ± 48.1^{a}
13	527	269.9 ± 38.2^{c}	609	274.0 ± 44.8^{c}	435	274.0 ± 41.5^{c}	596	282.7 ± 43.4^{b}	524	344.0 ± 49.0^{a}
14	527	291.2 ± 41.3^{c}	618	298.4 ± 45.9^{c}	443	298.6 ± 41.9^{c}	611	307.8 ± 45.3^{b}	524	377.8 ± 50.0^{a}
15	513	314.7 ± 43.4^{d}	605	323.0 ± 47.6^{cd}	440	325.9 ± 43.7^{c}	600	334.9 ± 45.7^{b}	502	413.4 ± 51.1^{a}
16	508	338.1 ± 44.4^{d}	600	348.3 ± 48.8^{c}	436	352.0 ± 44.0^{c}	591	361.6 ± 46.0^{b}	498	447.5 ± 51.8^{a}
17	504	361.0 ± 47.7^{d}	608	374.7 ± 51.0^{c}	441	377.3 ± 45.7^{c}	602	387.1 ± 47.1^{b}	495	481.3 ± 51.7^{a}
18	489	386.1 ± 51.2^{d}	591	402.1 ± 55.8^{c}	428	403.8 ± 49.1^{c}	576	417.3 ± 50.2^{b}	487	515.4 ± 52.2^{a}
19	492	411.5 ± 54.9^{d}	595	430.3 ± 60.8^{c}	428	431.0 ± 52.4^{c}	578	448.2 ± 54.0^{b}	480	543.1 ± 51.1^{a}
20	477	439.2 ± 59.6^{d}	572	461.0 ± 66.2^{c}	415	460.6 ± 57.7^{c}	553	481.8 ± 57.4^{b}	473	565.3 ± 48.0^{a}
21	478	468.0 ± 64.0^{d}	579	491.3 ± 69.2^{c}	415	492.1 ± 63.5^{c}	556	511.7 ± 58.4^{b}	456	578.5 ± 47.5^{a}
22	463	499.4 ± 67.2^{d}	567	521.3 ± 70.7^{c}	404	523.6 ± 63.9^{c}	532	537.3 ± 59.2^{b}	393	590.5 ± 51.6^{a}
23	464	528.3 ± 68.6^{c}	556	549.1 ± 69.2^{b}	390	551.5 ± 62.5^{b}	499	558.5 ± 57.9^{b}	307	599.1 ± 59.7^{a}
24	457	553.7 ± 68.5^{c}	542	567.1 ± 64.1^{b}	389	572.7 ± 56.7^{b}	456	573.5 ± 58.4^{b}	248	603.9 ± 74.4^{a}

Notes: means in each row followed by different letters are significantly different from one another on the results of comparison using the Tukey test (P < 0.05).

Table 2
Growth dynamics of heifers that survived to the first calving and left the herd (kg)

Age, months	Left before the first calving		Survived until the first calving		Probability
	n	x ± SD	n	x ± SD	P
0	1171	30.5 ± 5.2	2348	32.5 ± 3.4	5.52×10^{-39}
1	923	44.2 ± 7.6	2338	47.1 ± 5.8	2.03×10^{-30}
2	848	61.0 ± 8.5	2346	64.8 ± 6.6	2.14×10^{-39}
3	721	78.9 ± 11.6	2306	85.3 ± 8.9	4.47×10^{-53}
4	627	100.1 ± 16.4	2346	106.3 ± 12.7	5.67×10^{-24}
5	591	120.1 ± 20.8	2323	127.2 ± 17.7	1.41×10^{-16}
6	563	137.5 ± 24.7	2309	145.1 ± 21.6	3.87×10^{-13}
7	539	153.4 ± 28.2	2346	162.8 ± 25.7	7.80×10^{-14}
8	509	171.1 ± 31.6	2311	181.8 ± 29.7	6.41×10^{-13}
9	495	187.2 ± 36.2	2346	200.5 ± 34.2	1.25×10^{-14}
10	472	204.7 ± 42.3	2307	221.7 ± 39.0	2.90×10^{-17}
11	441	223.6 ± 46.9	2299	243.4 ± 42.9	4.09×10^{-18}
12	430	243.6 ± 51.0	2346	267.1 ± 46.7	6.39×10^{-21}
13	386	266.2 ± 54.7	2305	292.5 ± 50.0	6.25×10^{-21}
14	377	289.0 ± 59.4	2346	318.5 ± 53.1	1.60×10^{-22}
15	356	315.2 ± 63.5	2304	345.7 ± 56.3	2.14×10^{-20}
16	321	338.8 ± 65.7	2312	372.8 ± 59.2	4.09×10^{-21}
17	303	364.1 ± 69.7	2347	399.3 ± 62.6	2.19×10^{-19}
18	258	387.4 ± 75.9	2313	428.3 ± 66.8	6.86×10^{-20}
19	231	412.3 ± 83.0	2342	455.8 ± 68.8	4.54×10^{-19}
20	186	440.4 ± 91.6	2304	484.5 ± 69.7	9.94×10^{-16}
21	162	465.3 ± 95.6	2322	510.5 ± 68.3	4.31×10^{-15}
22	133	494.4 ± 97.9	2226	534.8 ± 66.8	6.09×10^{-11}
23	113	521.4 ± 101.2	2103	556.0 ± 64.7	1.03×10^{-7}
24	98	554.5 ± 105.8	1994	571.8 ± 62.7	0.011

Table 3
Stayability of repair heifers with different birth years (%)

Age, days	Year of birth					Value χ^2 (P)
	2013 (n = 668)	2014 (n = 776)	2015 (n = 595)	2016 (n = 808)	2017 (n = 672)	
90	90.1	88.5	85.0	82.4	92.1	0.283
180	86.4	82.7	77.3	78.2	90.5	0.040
270	83.5	81.2	75.6	76.6	87.6	0.083
360	81.0	80.5	75.0	76.0	82.1	0.468
450	78.1	79.6	74.5	75.5	76.9	0.817
540	74.9	77.6	72.9	73.0	73.2	0.813

At the same time, the average live weight of heifers at first insemination differed by only 25 kg. The influence of the year of birth on this indicator was significant, but very weak (η^2 = 1.0%, P < 0.001). This is because the main criterion for transferring heifers to the insemination group was live weight, which had to exceed 360 kg. The growth rate of heifers born in different years varied, with the level of feeding having a significant impact. Similarly, the live weight of heifers in their first lactation also depended on the level of feeding in different years.

There were notable differences between the mean values of the weight of heifers born in different years, with a maximum difference of 52 kg. The effect of the year of birth was also significant, reaching 9.4% (P < 0.001). Furthermore, there were notable differences in the mean values of live weight gain among first-born cows during the period from insemination to the first lactation ($\eta^2 = 7.7\%$, $P < 0.001$). The range of differences between groups was from 10 to 76 kg. The maximum difference in the average live weight of cows of the second lactation born in different years was less than in the first lactation, amounting to 42 kg. Concurrently, the strength of the influence of the year of birth on this indicator also decreased ($\eta^2 = 1.9\%$, $P < 0.001$). This may be attributed to a decline in growth intensity associated with age.

A study revealed that first-born cows from different years of birth exhibited notable variations in both milk yield and fat content. The impact of the studied factor on the performance indicators of firstborn cows was as follows: for milk yield during the first 90 days of lactation – 20.9%, for milk yield during the first 150 days of lactation – 28.2%, for milk yield during 305 days of lactation – 29.4%, for the percentage of fat in milk – 10.6% ($P < 0.001$). The average values of these indicators indicate that the groups differed by up to 798 kg, up to 1317 kg, up to 2325 kg, and up to 0.17%. This also indicates the influence of the level of feeding in different years on the milk yield of firstborn cows (Table 6).

The results indicated that the lactation curve of animals inseminated in the first lactation and calved in the second calving exhibited a classic appearance (Table 7). The firstborn calves culled before the second calving demonstrated significantly lower milk yields in the first months ($P < 0.001$). Therefore, the average daily milk yield of cows that survived to the second calving was higher than that of the cows culled in the first and second month of lactation by 4.1–4.3 kg. Over the subsequent months of lactation, the difference decreased, reaching 0.7 kg by month 10, which was not significant. This suggests that at the outset of lactation, firstborn cows are less productive in terms of daily milk yield. As lactation progresses, the number of cows culled for reproductive issues rises.

Table 4
Stayability of animals of different years of birth until the second calving

Stayability:	Year of birth					Value χ^2 (P)
	2013	2014	2015	2016	2017	
Until the first fertilization	63.9	70.9	67.4	63.6	67.9	0.388
Until the first calving	63.9	70.9	67.4	63.6	67.9	0.388
Until the 90th day of lactation	53.1	55.8	62.4	56.2	57.3	0.285
Until the 150th day of lactation	51.3	53.5	61.2	53.6	54.2	0.173
Until the second calving	46.1	47.3	50.8	42.5	48.4	0.221

Table 5
Age of first insemination and dynamics of live weight of animals from insemination to the second lactation

Year of birth	Age of first insemination, days		Live weight at first insemination, kg		Live weight of cows of first lactation, kg		Live weight of second lactation cows, kg		Weight gain from insemination to first lactation, kg	
	n	x ± SD	*n*	x ± SD	*n*	x ± SD.	*n*	x ± SD	*n*	x ± SD
2013	427	574 ± 83^{a}	419	449 ± 95^{a}	415	504 ± 60^{b}	182	555 ± 81^{b}	407	54 ± 100^{d}
2014	550	541 ± 79^{b}	536	432 ± 89^{b}	523	507 ± 54^{b}	301	571 ± 83^{b}	510	76 ± 93^{c}
2015	401	535 ± 71^{b}	391	438 ± 90^{ab}	396	535 ± 61^{a}	282	572 ± 70^{b}	386	98 ± 101^{b}
2016	514	508 ± 62^{c}	501	424 ± 82^{b}	478	544 ± 70^{a}	259	564 ± 79^{b}	467	120 ± 95^{a}
2017	457	445 ± 66^{d}	443	428 ± 79^{b}	425	556 ± 71^{c}	114	597 ± 79^{a}	412	130 ± 89^{a}

Notes: means in each column followed by different letters are significantly different from one another on the results of comparison using the Tukey test ($P < 0.05$).

Table 6
Milk yields by lactation periods and fat content in milk of first-born heifers of different years of birth

Year of birth	Milk yield for the first 90 days of lactation, kg		Milk yield for the first 150 days of lactation, kg		Milk yield for 305 days of lactation, kg		Percentage of fat per lactation, %.	
	n	x ± SD	*n*	x ± SD	*n*	x ± SD	*n*	x ± SD
2013	355	1561 ± 446^{d}	343	2731 ± 680^{d}	408	4398 ± 1254^{c}	339	3.61 ± 0.21^{d}
2014	433	1745 ± 525^{c}	415	3007 ± 782^{c}	469	4950 ± 1525^{c}	425	3.67 ± 0.16^{c}
2015	371	2128 ± 535^{b}	364	3590 ± 737^{b}	377	6383 ± 1360^{b}	359	3.78 ± 0.24^{a}
2016	454	2207 ± 590^{b}	433	3864 ± 840^{a}	448	6723 ± 1402^{a}	419	3.73 ± 0.21^{b}
2017	385	2359 ± 611^{a}	364	4048 ± 813^{a}	336	6588 ± 1443^{a}	302	3.76 ± 0.14^{ab}

Notes: as in Table 5.

Table 7
Dynamics of changes in daily milk yields of first-born heifers that were discarded and those which survived to the second calving

Month of lactation	Firstborns discarded during lactation		First-born cows that survived to the second calving		Value
	n	x ± SD	n	x ± SD	P
1	546	16.2 ± 9.4	1645	20.3 ± 7.5	3.25×10^{-24}
2	467	18.3 ± 9.6	1645	22.6 ± 7.5	2.28×10^{-23}
3	352	21.7 ± 9.4	1645	24.3 ± 7.2	1.14×10^{-8}
4	301	22.4 ± 9.1	1645	24.4 ± 7.0	2.79×10^{-5}
5	272	22.0 ± 8.9	1645	23.8 ± 7.1	2.19×10^{-4}
6	243	21.2 ± 8.2	1643	23.4 ± 7.0	8.29×10^{-6}
7	218	21.1 ± 8.6	1639	22.8 ± 7.0	0.001
8	189	20.4 ± 8.6	1637	22.0 ± 6.9	0.003
9	165	19.7 ± 8.2	1625	21.1 ± 7.1	0.013
10	143	19.7 ± 7.8	1488	20.4 ± 7.7	0.260

In analyzing the results of the effect of the year of birth on the reproductive capacity of animals, the following should be noted: The analysis revealed that feeding conditions in different years had a significant impact on the average duration of the first service period ($\eta^2 = 0.7\%$, $P < 0.05$). Accordingly, the duration of the service period exhibited a range of 0 to 23 days between groups. Furthermore, no discernible pattern in these fluctuations could be identified. This indicates that the duration of the first service period did not depend on the milk yield of the firstborn cows, but differed by the year of their birth (Table 8). It should be noted that in the first pregnancy, the percentage of stillborn calves was the highest in 2017 and had significant differences. There were no differences in the number of abortions. In the second pregnancy, there were no significant differences in these indicators.

The study revealed that animals born in different years exhibited variations in growth intensity, reproductive capacity, and milk production. Notably, there was a discernible trend towards enhanced milk productivity in first-born heifers, accompanied by an increase in live weight gain from insemination to the first lactation. The results of the correlation analysis indicated a significant ($P < 0.01$) relationship between age ($r = -0.209 \pm 0.024$) and live weight ($r = -0.751 \pm 0.017$) at first insemination, milk yield in 90 days ($r = 0.163 \pm 0.024$), milk yield in 150 days ($r = 0.165 \pm 0.024$) and milk yield in 305 days ($r = 0.161 \pm 0.024$) of lactation, live weight in the first lactation ($r = 0.504 \pm 0.022$), as well as with stayability up to 90 days of lactation ($r = 0.133 \pm 0.025$) and 150 days of lactation ($r = 0.159 \pm 0.024$). In this regard, as well as according to the literature data indicating a negative energy balance in the body of cows in the first period of lactation, we analyzed the effect of this increase in milk production, reproductive capacity and safety of firstborn calves.

In accordance with the methodology, the first-born cows were classified based on the value of this increase. The mean values for the age of first insemination, and live weight during insemination in the first and second lactation were calculated for the groups (Table 9).

Table 8
Indicators of the reproductive capacity of first-born cows

Year of birth	The first pregnancy			Service period, days*		The second pregnancy		
	n	stillborn calves, %	abortions, %	n	x ± SD	n	stillborn calves, %	abortions, %
2013	427	2.1	1.4	308	138 ± 107[b]	308	1.9	1.9
2014	550	2.2	1.8	366	146 ± 90[ab]	366	3.8	2.2
2015	401	4.0	3.7	297	138 ± 102[b]	297	4.4	3.4
2016	514	4.3	2.3	321	161 ± 116[a]	321	2.2	3.7
2017	457	12.3	3.7	230	144 ± 87[ab]	230	2.2	1.7
Value χ^2 (P)		1.15×10^{-13}	0.088	–	–	–	0.272	0.459

Notes:* as in Table 5.

Table 9
Age at first insemination and live weight of animals from insemination to the second lactation

Difference between weight in the first lactation and at first insemination, kg	Age of first insemination, days		Weight at first insemination, kg		First lactation weight, kg		Second lactation weight, kg	
	n	x ± SD	n	x ± SD	n	x ± SD	n	x ± SD
<56	714	537 ± 94[a]	714	518 ± 96[a]	714	498 ± 71[c]	379	575 ± 73[a]
56-146	744	531 ± 73[a]	744	400 ± 45[b]	744	510 ± 46[b]	336	557 ± 82[b]
>146	724	490 ± 73[b]	724	383 ± 29[c]	724	578 ± 50[a]	356	576 ± 80[a]

Notes: as in Table 5.

The animals with the lowest live weight gain from insemination to the first lactation had the highest age and live weight at first insemination and the lowest weight in the first lactation. Conversely, the animals with the highest gain during this period were significantly lower in age and live weight at insemination and had the highest weight in the first lactation. The strength of the effect of this increase was 6.1%, 47.1%, and 28.0%, respectively. The difference between the first and third groups was 47 days, 135 kg, and 80 kg ($P < 0.001$). This indicates that the animals of the third group had a higher growth rate and were inseminated immediately after reaching the live weight required for insemination. As for the live weight of cows in the second lactation, the differences between the groups were only 1–19 kg ($P < 0.01$).

An important indicator in dairy farming is cow stayability. Table 10 shows the results of a two-factor analysis of variance for the stayability of first-born cows during the inter-calving period, depending on the year of birth and the above-mentioned weight gain.

Table 10
Stayability of first-born heifers of different years of birth during lactation depending on the increase in live weight from the first insemination to the first lactation

Year of birth	Difference between live weight in the first lactation and at insemination, kg	n	Stayability of first-born heifers, %.		
			up to 90 days	up to 150 days	up to the 2nd calving
2013	<56	184	82.6	77.7	72.3
	56-146	158	82.9	81.0	72.2
	>146	65	86.2	86.2	73.8
	Value χ^2 (P)	–	8.94×10^{-15}	9.02×10^{-15}	3.94×10^{-12}
2014	<56	173	67.6	62.4	60.7
	56-146	219	81.3	77.6	65.3
	>146	118	92.4	92.4	79.7
	Value χ^2 (P)	–	1.57×10^{-06}	3.48×10^{-06}	5.26×10^{-05}
2015	<56	108	89.8	86.1	83.3
	56-146	152	90.8	88.8	69.1
	>146	126	96.8	96.8	76.2
	Value χ^2 (P))	–	0.06	0.06	0.20
2016	<56	136	86.0	77.2	72.8
	56-146	135	77.8	74.1	54.1
	>146	196	95.4	93.9	69.4
	Value χ^2 (P)	–	4.36×10^{-4}	4.55×10^{-4}	4.32×10^{-3}
2017	<56	113	73.5	66.4	61.1
	56-146	80	71.3	62.5	56.3
	>146	219	96.3	94.5	83.6
	Value χ^2 (P)	–	1.93×10^{-19}	5.88×10^{-20}	4.14×10^{-19}
Total for all the years	<56	714	79.3	73.4	69.5
	56-146	744	81.9	78.4	64.5
	>146	724	94.6	93.6	76.9
	Value χ^2 (P)	–	1.13×10^{-38}	8.81×10^{-39}	8.09×10^{-33}

The best stayability up to the 90th day of lactation was observed in first-born heifers with a higher live weight gain from the first insemination to weighing in the first lactation. This trend was maintained in animals regardless of their year of birth. However, as mentioned above, the values differed in different years. The strength of the influence of the factors was as follows: year of birth (1.5%), weight gain (2.7%), and combined effect (1.6%, $P < 0.001$). It should be noted that, on average, the survival rate of all first-born calves with a gain of more than 146 kg was 13–16% higher than that of animals with a smaller gain.

Similar results were obtained for the stayability of first-born heifers up to the 150th day of lactation. Animals with higher live weight gain from the first insemination to weighing in the first lactation had better stayability. This tendency was observed in animals regardless of the year of birth, but its values differed in different years. The analysis revealed that the year of birth, weight gain, and the combined effect had a significant impact on the survival rate of first-born calves, with the year of birth having the greatest influence (1.8%), followed by weight gain (4.1%) and the combined effect (1.5%). Furthermore, the survival rate of all first-born calves with a weight gain of more than 146 kg was found to be 16–21% higher than that of animals with a lower weight gain (Table 10).

Concerning the survival of cows to the second calving, the aforementioned trend was not observed in animals born in 2015–2016. However, the overall trend remained consistent across all years. On average, the safety of all first-born cows with a weight gain of more than 146 kg was 8–12% higher than that of animals with a lower weight gain. The impact of the factors was less pronounced, with the year of birth contributing 0.7%, weight gain 1.2%, and the combined effect 1.5% (P < 0.001). It is important to note that the number of cows that remained in the second lactation period was 4% higher in the group with the lowest growth compared to the average increase in live weight.

The animals with the highest milk yields for all lactation periods were those with weight gains above 146 kg. The advantage in milk yield was 234 kg for the first 90 days of lactation, 331–381 kg for 150 days, and 573–675 kg for 305 days (P < 0.001). The impact of the studied factor ranged from 3.3% to 3.6%. It is noteworthy that the lowest milk yields for 150 and 305 days of lactation were observed in first-born cows with average growth (Table 11).

The average daily milk yield of cows in the third group was significantly higher compared to animals in the first and second groups (Table 12). The advantage in milk yield of this group over others by months of lactation was as follows: 1st month – 2.9–3.0 kg of milk per day, 2nd month – 3.2–3.4 kg, 3rd month – 2.7–2.8 kg, 4th month – 2.2–2.8 kg, 5th month – 2.2–2.7 kg and subsequent months of lactation from 1.1 to 2.6 kg (P < 0.001). The decrease in the difference between these groups is explained by the higher cull rate of the firstborns of the first two groups. During the first 90 days, 4–6% of the animals were discarded, and only 1% of the third group. The main reason for discarding during this period was low productivity.

Table 11
Milk production of first-born cows depending on growth intensity after the first insemination

Difference between weight during the first lactation and at insemination, kg	Milk yield for 90 days, kg		Milk yield for 150 days, kg		Milk yield for 305 days, kg	
	n	x ± SD	n	x ± SD	n	x ± SD
<56	565	1912 ± 625[b]	523	3356 ± 944[b]	463	6467 ± 1664[b]
56–146	609	1912 ± 577[b]	583	3306 ± 862[b]	493	6365 ± 1610[b]
>146	685	2146 ± 604[a]	677	3687 ± 888[a]	572	7040 ± 1656[a]

Notes: as in Table 5.

Table 12
Dynamics of daily milk yield of first-born heifers with different growth intensity after the first insemination (kg)

Month of lactation	Difference between weight during the first lactation and at insemination, kg					
	<56		56–146		>146	
	n	x ± SD	n	x ± SD	n	x ± SD
1	650	18.1 ± 8.0[b]	690	18.0 ± 7.8[b]	706	21.0 ± 8.3[a]
2	625	20.1 ± 8.5[b]	655	20.4 ± 7.7[b]	694	23.6 ± 7.8[a]
3	565	22.6 ± 8.0[b]	609	22.7 ± 7.4[b]	685	25.4 ± 7.3[a]
4	533	23.3 ± 7.6[b]	595	22.7 ± 7.2[b]	681	25.5 ± 7.1[a]
5	523	22.8 ± 7.6[b]	583	22.3 ± 7.2[b]	677	25.0 ± 7.3[a]
6	514	22.5 ± 6.9[b]	573	21.9 ± 7.2[b]	667	24.4 ± 7.0[a]
7	507	22.0 ± 6.7[b]	566	21.3 ± 7.3[b]	656	23.9 ± 7.3[a]
8	503	21.5 ± 6.5[b]	557	20.7 ± 7.4[b]	643	22.9 ± 7.3[a]
9	500	20.8 ± 6.7[b]	543	19.8 ± 7.4[b]	627	21.9 ± 7.2[a]
10	451	19.3 ± 6.9[b]	493	19.4 ± 7.5[b]	577	21.7 ± 8.4[a]

Notes: as in Table 5.

The results of the analysis of variance revealed that groups of animals with varying live weight gain after the first insemination exhibited notable differences in the number of stillborn calves (0.6–2.9%, P < 0.05) and the duration of the service period (9–26 days, P < 0.001). The impact of growth intensity on these reproductive capacity indicators was found to be 1.1% (Table 13).

Table 13
Reproductive capacity of cows depending on weight gain and insemination before the first lactation

Difference between weight during the first lactation and at insemination, kg	The first calving			Service period, days*		The second calving		
	n	stillborn calves, %	abortions, %	*n*	x ± SD	*n*	stillborn calves, %	abortions, %
<56	714	3.6	2.9	489	132 ± 92[b]	489	2.9	3.3
56–146	744	4.2	2.2	446	158 ± 113[a]	446	3.6	2.2
>146	724	6.5	2.1	492	149 ± 99[a]	492	2.8	2.8
Value χ^2 (P)	–	0.031	0.497	–	–	–	0.765	0.642

Notes: * as in Table 5.

An increase in the number of stillborn calves may be explained by their higher live weight, which caused birth complications, and a shorter service period in the firstborn heifers of the first group – by their low milk yield. The correlation coefficient between the service period and milk yield for 305 days of lactation was 0.127 ± 0.026 (P < 0.01).

Discussion

The primary objective of the dairy herd restoration program is to raise heifers in a cost-effective manner, ensuring they reach the desired body size and weight to achieve optimal genetic milk production throughout their lives (Hawkins et al., 2020; Paliy et al., 2021). Our research has determined that the primary criterion for transferring heifers to the insemination group is live weight, which should exceed 360 kg. There were notable differences in the average weight of first-born heifers born in different years, with a difference of 52 kg, and of second-lactation cows, with a difference of 42 kg. There was also a significant difference in the average values of live weight gain during the period from insemination to the first lactation for first-born cows, with a difference of 7.7% and a P-value of less than 0.001. The differences between groups ranged from 10 to 76 kg.

Economic analysis of other studies has also confirmed that larger, well-bred heifers were more profitable due to better productive potential, all other things being equal (Busanello et al., 2022). Various researchers have found that from the moment of birth, calves are exposed to pathogens responsible for the main symptoms of calf disease (Svensson et al., 2006; Hultgren et al., 2008). The cost of the disease is not limited to the cost of veterinary drugs or preventive treatment, as it also has a long-term economic impact due to reduced average daily gain, increased culling and a later age at first calving, leading to an increased unproductive period (Bach et al., 2008; Heinrichs & Heinrichs, 2011). Our studies have shown that differences in heifer stayability in different years up to 3 months of age were 9.7%, up to 6 months – 13.2%, up to 9 months – 12.0%, and up to one year of age – 7.2%. It should be noted that, on average, the survival rate of all first-born cows with a weight gain of more than 146 kg was 13–16% higher than that of animals with a lower weight gain. Also, cows with an increase of more than 146 kg had the highest milk yields for all lactation periods. Their advantage in milk yield was 234 kg for the first 90 days of lactation, 331–381 kg for 150 days of lactation, and 573–675 kg for 305 days of lactation.

The study is fully consistent with the data obtained by other scientists who have established a positive relationship between pre-calving body weight and milk production in the first lactation (McNaughton & Lopdell, 2013; Eetvelde et al., 2017). These results indicate that higher productivity can be achieved during the first and second lactations by raising heifers to a higher body weight. In our studies, there was a tendency for the milk production of first-born heifers to improve with an increase in live weight gain from insemination to the 1st lactation. Animals with the highest growth during this period were significantly different in age and live weight at insemination and had the highest weight in the first lactation.

However, in the initial months of lactation, the live weight of the firstborn calves exhibited a slight decline, indicating a negative energy balance in the cows during this period. Other researchers have also highlighted the fact that when cows begin producing milk after calving, they mobilize body reserves to compensate. This typically results in weight loss during the initial weeks of lactation. At the individual animal level, excessive mobilization of body reserves can lead to health issues such as metabolic problems (Vanholder et al., 2015; Rathbun et al., 2017), a reduced immune response, and an increased risk of infectious diseases, as well as reduced fertility (Bronzo et al., 2020; Chida et al., 2021), and reduced milk quality regardless of the sanitary conditions of its production (Aliiev et al., 2022; Moschovas et al., 2023). This negatively impacts the long-term viability of the dairy industry and its economic profitability.

Conclusion

The development and implementation of effective systems for rearing replacement cattle is an important issue in livestock technology. These systems should include a set of measures for feeding, housing, and caring for animals. It is therefore essential to consider the specific growth and development characteristics of animals when raising them, in order to achieve the genetically programmed productivity that is desired. Our studies have confirmed that animals with the highest live weight gain were significantly different in terms of lower age at insemination, as well as the highest live weight in the first lactation and better productivity. However, they had some problems with reproduction (slightly longer service period). Therefore, the early maturity of replacement heifers contributes to intensive reproduction of the herd and increases the level of profitability of dairy farming.

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