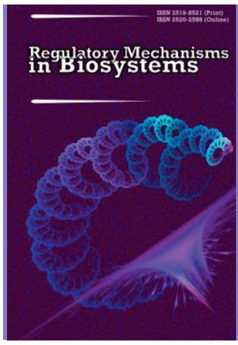

Regulatory Mechanisms in Biosystems

ISSN 2519-8521 (Print)
ISSN 2520-2588 (Online)
Regul. Mech. Biosyst.,
2023, 14(1), 118–124
doi: 10.15421/022318

Peculiarities of growth and further productivity of purebred and crossbred cows

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Article info

Received 06.02.2023
Received in revised form 07.02.2023
Accepted 02.03.2023

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Bashchenko, M. I., Boiko, O. V., Honchar, O. F., Sotnichenko, Y. M., Lesyk, Y. V., Iskra, R. Y., & Gutyj, B. V. (2023). Peculiarities of growth and further productivity of purebred and crossbred cows. Regulatory Mechanisms in Biosystems, 14(1), 118–124. doi:10.15421/022318

Use of genetic specifics of pure breeding in animal husbandry allows cross breeders to produce herds that are completely of high breeding value, and also improve genetic potential of the best breeds. A relevant issue is determining the efficiency of crossbreeding of dairy breeds by analyzing the growth intensity of young bovine cattle, their reproductive ability and dairy productivity. We performed an analysis of experimental studies of using effective methods of selection, carried out a theoretical analysis, formulated hypotheses, used genealogical, biometrical and statistical methods, and assessed the productive properties of animals. We determined that the heifers from cross of the Ukrainian Red-Spotted cows with the sires of the Montbeliard breed – compared with the heifers from the Holstein bulls – had higher growth intensity and greater live weight during all the age periods. From birth until the age of one year, the Ukrainian Black-Spotted dairy heifers from the Holstein and Norwegian Red sires had no significant difference in weight. The heifers that resulted from cross of the Montbeliard and Ukrainian Red-Spotted dairy breeds had advantages over the purebred animals during all age periods, namely in the measurements of chest width, hook bone width, chest girth, ring metacarpal length. Body measurements of the replacement heifers, derived from the Norwegian Red and Holstein sires, varied within insignificant ranges depending on genotype, without significant difference. The animals were compact and proportionate; having received sufficient and complete diets, they had satisfactory weight categories. We determined that increase of the age of first insemination and first pregnancy was followed by decrease in the dairy productivity of cows. It ranged 0.021 to 0.064 in the bred heifers of different genotypes and breeds. There was observed an insignificant direct relationship between the abovementioned factors and the contents of fat and protein in milk. The shares of influence of age when the animals were first inseminated on milk yield accounted for 7.1% to 11.4%, 5.4–6.9 on fat content in milk, and 8.0–12.2% on protein fraction in milk. Crossbreeding can efficiently decrease the percentage of complicated deliveries and stillbirth rate, which in turn decreases the expenses for treatment of consequences of difficult calving, including the risk of decline in milk productivity and longer calving interval. However, there should be a careful approach to the selection of a breed, sire (preferably, its evaluation should be taken into account according to calving ease, especially when using the Montbeliard breed) and analysis of dams that are to be crossed with. Upgrading by mating to the Montbeliard and Norwegian breeds resulted in the crossbred cows that produced the greatest profit due to their heightened productivity. We should note that the estimated prices of extra products per cow give us grounds to state a positive effect from crossbreeding with the Montbeliard and Norwegian Red breeds. The performed studies confirm the benefits of identifying the efficiency of crossbreeding dairy breeds by an analysis of growth intensity of young bovine cattle.

Keywords: growth; development; analyzing cross breeding; Holstein; Montbeliard; Norwegian Red.

Introduction

Intensive raising of calves can be an effective way of decreasing the age of first calving without negative effect on milk yield or the economics (Davis Rincker et al., 2011). The growth rates of heifers and their body weight during first calving are considered important benchmarks in the management of dairy farms (Funston & Deutscher, 2004; Handcock et al., 2020). Increase in the growth rates can shorten the time of non-productive use of breeding stock (Funston & Deutscher, 2004), but excessive growth tempos can lead to decrease in milk production in the future (Heins et al., 2018; Hazel et al., 2021). Furthermore, recommendations for optimal timing and weight during first labor vary considerably. Those factors are associated with how intensely the animals had been used and their genotype (Hazel et al., 2021; Pryima et al., 2021). When using high-intensity technologies, the Holstein genetic potential is recommended to be used when cows reach the body weight ranging 540 to 650 kg before first calving (Macdonald et al., 2005; Schubach et al., 2019); slower growth implies the live weight during first labor within 490 to 550 kg (Polupan et al., 2021).

Over the recent decades, the search of a more productive dairy cow has led to the broad use of crossbreeding. The interest to this method of raising has increased both among producers of dairy-goods and researchers (Polupan et al., 2021). Many recent studies compared the Holsteins with crosses of F1 with the Jersey breed (Bjelland et al., 2011), Brown Swiss (Bjelland et al., 2011; Blöttner et al., 2011; Bashchenko et al., 2021) and European breeds, such as Normand, Montbeliard and Scandinavian Red breeds (Buckley et al., 2014). By introducing crossbreeding of dairy breeds, farmers expect improvement in the general herd productivity. However, they lack knowledge on how to manage genetic diversity of classes created as a result of rotational crossbreeding (Quénon & Magne, 2021). Crossbreeding in dairy livestock farming, which has recently been used actively, needs additional knowledge about how to use diversity of genotypes developed by rotational crossbreeding (Siriak et al., 2019; Dynko et al., 2021; Polupan et al., 2021). In recent years, some farms have been practicing test cross of the domestic breeds by mating Black- and Red-Spotted dairy cows to sires of Holstein, Montbeliard and Norwegian Red breeds (Bashchenko et al., 2021). Their offspring was characterized by specific genetic and genealogical structures and requires consolidation, both according to the exterior-type traits (Stavetska & Dynko, 2021) and growing intensity (Hladiy et al., 2018).

The genotype and environment interact, and therefore the productive potentials of animals are realized completely. Growth intensity of crossbred young cattle of the first and second generations, and also three-breed animals, was 2.3–3.4% higher than such of purebred animals (Khmelnychyi & Karpenko, 2021). With age, the crossbred and purebred heifers demonstrated notable dairy type, while the crossbred animals had higher measurement parameters than the purebred peers. Therefore, they were superior to the peers according to chest girth, diagonal body length, and ring metacarpal length by 2.9%, 3.1%, and 5.2%, respectively (Bashchenko et al., 2021a).

The effectiveness of various variants of selection breeding programs in the populations of domestic dairy breeds, their effect on the intensity of growing young cattle and non-productive periods of the animals are no doubt relevant and practically important questions.

The objective of the study was determining the efficiency of crossbreeding of dairy breeds by analyzing the growth intensity of young bovine cattle, theire reproductive ability and dairy productivity.

Materials and methods

The experimental studies were performed in compliance with the Law of Ukraine No. 3447-IV as of 02/21/06 "On Protection of Animals against Abuse", according to the main principles of the "European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes" (Strasbourg, 1986), the Declaration "On Humane Treatment of Animals" (Helsinki, 2000) and the "General Ethic Principles of the Experiments on Animals" adopted by the National Congress of Bioethics (Kyiv, 2001). During the studies, the maintenance conditions and treatment of cows corresponded to their physiological, species-specific, natural and individual needs (Laws of Ukraine No. 3447-IV as of 21.02.2006 and No 5456-VI as of 10.16.2012), and also their needs for nutrition were satisfied (feeding with high-nutritive mixed feeds balanced in terms of micro- and macroelements with the following nutrition values (cow per year): metabolism energy of 65,500 mJ, energy feed units – 6,540 EFU, dry matter – 5,950 kg, digestible protein [fraction of raw protein that is absorbed from the digestive tract into lymph and blood] – 624.3 kg, dry cellulose – 1,190 kg, water. The animals had rest (special boxes with the area equaling 1.9–2.5 m^2 for milked and dry cows, 3.0 m^2 in the birth-giving room, 1.8 m^2 for the young, with warm, dry litter), mobile activity (8–10 m^2 grazing-feeding ground, 0.8–1.0 m per individual feeding spot. The ratio of feeding spots to animals in a section was 1:1). In the technological processes of milking (milking parlors of parallel type), the veterinary monitoring did not use pain-causing and traumatic methods, and the sanitary-hygienic norms of exploitation and regarding the equipment were adhered to. The crossbreeding methods caused no painful genetic changes in the crossbred animals. If needed, the animals received timely veterinary help (Article 21, expanded by the fifth part in accordance to Law No. 1684-IX as of 07.15.2021 – took effect on 11.08.2021). During the earmarking and horn removal, anesthesia was used.

The studies were performed in 2020–2021 in the conditions of the Lan Agricultural Ltd. (41 individuals of Ukrainian Black-Spotted (UBS) heifers, 31 ind. of crosses between F1 Ukrainian Black-Spotted and Norwegian Red (genotype 1/2UBS1/2NR), 46 ind. of crosses of F2 Ukrainian Black-Spotted dairy, Norwegian Red and Holstein breeds (genotype 1/4UBS1/4NR1/2H), 51 ind. – hybrids of F2 Ukrainian Black-Spotted dairy, Holstein and Norwegian Red breeds (genotype 1/4UBS3/4NR) of Chornobaivka district; the Prohres Scientific-Research Group Ltd (20 ind. of UBS, 21 ind. of Ukrainian Red-Spotted dairy heifers (URS), 29 ind. of crosses between F1 Ukrainian Red-Spotted dairy and Montbeliard breeds (genotype 1/2URS1/2M), 30 ind. – hybrids of F2 Ukrainian Red-Spotted dairy, Holstein and Montbeliard (genotype 1/4URS1/4НЧ1/2H); Zolotonivske Agricultural Herd Livestokock Ltd. (52 ind. of Holsteins (H), 36 ind. of URS, 14 ind. of crosses of F1 of genotype 1/2URSx1/2M, 22 ind. of crosses F2 of genotype 1/4URS1/4M1/2H) of Zolotonosha district, the Vidrodzhennia Private Rented Daughter Enterprise (31 ind. of URS, 23 ind. – of crosses of F1 genotype 1/2URSx1/2M, 44 ind. of crosses F2 genotype 1/4URS3/4M) of Shpola district.

The intensities of growth and development of the purebred and crossbred heifers were compared based on the data of zootechnical and breeding accounts during raising of the replacement young produced in 2020–2021. Decline in the relative growth rates of replacement heifers and index of decline in the growth energy were determined using the methods (Svechin & Dunaev, 1989). The parameters of growth intensity of the animals were determined by the methods (Svechin & Dunaev, 1989).

The results of the study were analyzed in the Statistica 7.0 software (StatSoft Inc., USA). The data in the tables are presented as x ± SD (mean ± standard deviation). To compare differences in the mean parameters between the control and experimental groups, we used the Tukey test, where the differences were considered significant at P < 0.05 for all the data.

Results

The heifers resulting from crosses between Ukrainian Red-Spotted breed and Montbeliard sires – as compared with the heifers from Holstein bulls – had higher intensity of growth and higher live weight during all the age periods: by 1.5–6.5 kg at 3 months, 6.9–29.5 kg at 6 months (P < 0.01), by 15.1–65.7 kg at 9 months (P < 0.001), and by 19.4–81.7 kg at 12 months (P < 0.001). The back crossing of 1/2URS1/2M cows and Holstein sires produced heifers that had no significant difference according to the live weight, compared with Ukrainian Red-Spotted heifers. Such a pattern was observed on both farms where back crossing was practiced. After birth, the 1/4URS1/4M1/2H genotype heifers had significantly greater live weight (by 3.4 kg) than their peers of Ukrainian Red-Spotted breed. Mating to Montbeliard sires resulted in replacement heifers that at the age of six months achieved the live weight of 200 kg (after mating to Holstein sires, the heifers' weight at 6-month age was 178.7–196.2 kg), over 380 kg at the age of one year (384.9–391.1 kg) against 304.6–310.6 kg of heifers from Holstein sires, depending on genotype (Table 1).

From birth to one year of age, there was no significant difference in weight between the replacement Ukrainian Black-Spotted heifers from sires of the Holstein and Norwegian Red breeds.

The greatest mean daily increments of animals from the Holstein sires and cows were observed during the period from birth to 6-month age (723.3–960.0 g, Table 2).

Later, up to the age of one year, this parameter gradually declined. From the Holstein sires, used in the herds of Ukrainian Red-Spotted and Black-Spotted dairy breeds, heifers were produced with mean-daily increments at the level of 733.3–838.9 g up to the age of 9 months.

The highest mean daily increments throughout the growing period were in the crossbred animals from the Ukrainian Red-Spotted dairy cows and Montbeliard bulls: 820.0 to 1272.2 g (P < 0.001) in the young of 1/2URS1/2M genotype, and 841.1–1224.4 g (P < 0.001) in 1/4URB3/4M genotype. Even after back crossing of the first-generation 1/2URS1/2M cows and Holstein sires, the increments in the produced heifers were at the level of 767.8 ± 11.1 g up to three-month age, 875.6 ± 10.9 g up to six-month age (which had significant advantage over URS peers resulted from Holstein sires, P < 0.001), 913.3 ± 13.5 g up to the age of 9 months, and 677.8 ± 11.6 g up to the age of one year.

The crossbreeding of the Ukrainian Black-Spotted dairy cows and Norwegian Red sires resulted in the mean daily increments at the level of 481.1–873.3 g. Increments in the heifers of 1/2UBS1/2NR and 1/4UBS3/4NR genotypes in the period after 6 months significantly exceeded the increments in the peers from Holstein sires, by 34.4–37.8 g (P < 0.05).

As the replacement heifers grew older, their growth intensity decreased, but to a various extent depending on a genotype. The highest growth intensity was characteristic of heifers of genotypes 1/2URS1/2M and 1/4URS3/4M (0.717–0.809). The highest intensity of the development was observed in the heifers from URS×M cross (0.202–0.214). Uniform growth rate depends largely on live weight and mean daily increments. Therefore, according to the index of growth uniformity, the advantage of replacement heifers with the hereditary basis of Monbeliard sires equaled 0.694–0.809, and 0.613–0.721 in the replacement heifers from Holstein sires.

Table 1
Live weight (kg) of the replacement heifers of the studied breeds and genotypes (x ± SD)

Breed or genotype	n	Age periods, months				
		0	3	6	9	12
URS	88	34.3 ± 0.7^{a}	105.3 ± 7.6^{a}	178.7 ± 7.4^{a}	252.7 ± 11.8^{a}	309.4 ± 15.9^{a}
UBS	61	38.7 ± 0.4^{b}	104.7 ± 9.4^{a}	180.2 ± 9.4^{a}	255.7 ± 8.6^{a}	310.6 ± 14.9^{a}
H	52	44.7 ± 0.3^{d}	109.8 ± 16.3^{a}	196.2 ± 21.4^{a}	258.7 ± 19.9^{a}	304.6 ± 22.1^{a}
1/2URS1/2N	66	35.8 ± 0.7^{a}	109.6 ± 8.3^{a}	203.9 ± 7.5^{b}	318.4 ± 11.7^{b}	384.9 ± 14.6^{b}
1/4URS1/4M1/2H	52	37.7 ± 1.0^{b}	106.8 ± 9.2^{a}	185.6 ± 8.9^{a}	267.8 ± 18.3^{a}	328.8 ± 20.0^{a}
1/4URS3/4M	44	36.1 ± 0.8^{a}	111.8 ± 16.3^{a}	208.2 ± 11.1^{b}	318.4 ± 26.4^{b}	391.1 ± 20.8^{b}
1/2UBS1/2NR	31	36.3 ± 0.7^{a}	108.3 ± 18.2^{a}	180.5 ± 8.7^{a}	259.4 ± 11.7^{a}	305.7 ± 11.6^{a}
1/4UBS1/4NR1/2H	46	39.2 ± 0.3^{c}	108.4 ± 9.7^{a}	180.1 ± 6.9^{a}	257.5 ± 13.9^{a}	309.7 ± 16.4^{a}
1/4UBS3/4NR	51	35.8 ± 0.6^{a}	106.8 ± 10.0^{a}	182.3 ± 8.5^{a}	260.9 ± 9.9^{a}	304.2 ± 16.0^{a}

Note: different letters in the column indicate that the samples of data significantly (P < 0.05) differ one from another according to the results of the Tukey test with the Bonferroni correction.

Table 2
Mean daily increments (g) of the replacement heifers of the studied breeds and genotypes (x ± SD)

Breed or genotype	n	Age periods, months			
		0–3	3–6	6–9	9–12
URS	88	788.9 ± 11.5^{b}	815.6 ± 12.4^{a}	822.2 ± 11.7^{b}	630.0 ± 12.1^{b}
UBS	61	733.3 ± 14.9^{a}	838.9 ± 11.1^{b}	838.9 ± 13.1^{b}	610.0 ± 12.3^{b}
H	52	723.3 ± 12.6^{a}	960.0 ± 11.0^{d}	694.4 ± 10.9^{a}	510.0 ± 10.9^{a}
1/2URS1/2M	66	820.0 ± 11.5^{c}	1047.0 ± 10.7^{e}	1272.2 ± 11.3^{d}	738.9 ± 10.9^{d}
1/4URS1/4M1/2H	52	767.8 ± 11.1^{b}	875.6 ± 10.9^{c}	913.3 ± 13.5^{c}	677.8 ± 11.6^{c}
1/4URS3/4M	44	841.1 ± 10.9^{c}	1071.1 ± 11.1^{e}	1224.4 ± 10.9^{d}	807.3 ± 11.0^{e}
1/2UBS1/2NR	31	800.0 ± 11.6^{bc}	802.2 ± 10.9^{a}	876.7 ± 12.2^{b}	514.4 ± 10.8^{a}
1/4UBS1/4NR1/2H	46	768.9 ± 11.0^{b}	796.7 ± 11.2^{a}	860.0 ± 14.1^{b}	580.0 ± 11.0^{ab}
1/4UBS3/4NR	51	788.9 ± 11.6^{b}	838.9 ± 11.8^{b}	873.3 ± 11.0^{b}	481.1 ± 12.0^{a}

Note: different letters – see Table 1.

The heifers from cross between Montbeliard and Ukrainian Red-Spotted dairy breeds – as compared with the purebred animals – had advantage during all the age periods according to the chest width, hook bone width, chest girth, and ring metacarpal length (Table 3). The replacement heifers of Ukrainian Red-Spotted dairy breed had advantage over their crossbred (1/2URS1/2M, 1/4URS3/4M and 1/4URS1/4M1/2H) peers, measuring 0.7–2.9 cm (P < 0.01) in the withers height at the age of 6 months and 0.6–2.5 cm at the age of 12 months; 4.4 – 6.1 cm greater hip height at the age of 6 months, and 0.2–2.2 cm at the age of 12 months. According to chest depth and diagonal body length, the difference was insignificant. During different age periods, the crossbred heifers had advantages over the purebred peers of Ukrainian Red-Spotted breed according to the following parameters: chest girth – 0.4 to 3.9 cm (P < 0.05) at the age of 6 months, 0.8 to 5.8 cm at the age of 12 months; hook bone width – 2.0 to 2.8 cm (P < 0.05) at the age of 6 months, and 0.2 to 3.7 cm (P < 0.05) at the age of 12 months.

Table 3
Measurements of the replacement heifers aged 6 to 12 months (x ± SD)

Breed/genotype	n	Measurements, cm							
		height		width		diagonal body length	chest depth	circumference	
		withers	hip	chest	hook bones			chest	metacarpal bone
6 months									
URS	88	100.5 ± 0.1^{ab}	104.6 ± 2.8^{b}	23.3 ± 1.8^{a}	26.8 ± 0.3^{a}	111.9 ± 1.1^{a}	48.9 ± 0.7^{b}	121.4 ± 1.4^{a}	8.6 ± 0.2^{b}
UBS	61	101.2 ± 0.3^{b}	104.8 ± 0.3^{b}	23.3 ± 0.1^{a}	27.6 ± 0.3^{a}	113.6 ± 0.3^{b}	47.5 ± 0.6^{a}	121.3 ± 0.3^{a}	7.4 ± 0.2^{a}
H	52	103.2 ± 0.9^{b}	105.1 ± 0.9^{b}	24.1 ± 0.4^{a}	28.7 ± 0.3^{b}	112.1 ± 1.0^{a}	49.2 ± 0.7^{b}	123.1 ± 2.1^{a}	8.8 ± 0.9^{b}
1/2URS1/2M	66	97.6 ± 1.2^{a}	98.5 ± 1.2^{a}	25.8 ± 1.2^{ab}	29.4 ± 0.9^{b}	111.1 ± 4.3^{a}	49.1 ± 1.7^{b}	125.2 ± 1.2^{b}	9.3 ± 0.1^{c}
1/4URS1/4M1/2H	52	99.8 ± 1.1^{a}	100.2 ± 2.1^{a}	23.8 ± 1.2^{a}	28.8 ± 1.0^{b}	112.8 ± 0.7^{ab}	46.8 ± 2.2^{a}	121.8 ± 0.3^{a}	8.8 ± 0.5^{b}
1/4URS3/4M	44	98.2 ± 0.5^{a}	99.4 ± 0.6^{a}	26.2 ± 1.0^{ab}	29.6 ± 1.3^{b}	110.8 ± 0.6^{a}	49.2 ± 0.3^{b}	125.3 ± 1.3^{b}	9.5 ± 0.3^{c}
1/2UBS1/2NR	31	102.4 ± 0.2^{b}	106.9 ± 0.1^{b}	23.5 ± 0.2^{a}	27.8 ± 0.3^{a}	112.8 ± 0.4^{ab}	48.8 ± 0.2^{b}	120.6 ± 0.5^{a}	7.3 ± 0.2^{a}
1/4UBS1/4NR1/2H	46	101.3 ± 0.5^{b}	103.8 ± 0.9^{b}	24.8 ± 1.1^{a}	28.6 ± 1.1^{b}	113.8 ± 1.3^{b}	48.9 ± 0.5^{b}	120.6 ± 1.7^{a}	7.3 ± 1.0^{a}
1/4UBS3/4NR	51	102.6 ± 1.1^{b}	104.6 ± 1.2^{b}	24.7 ± 1.0^{a}	28.8 ± 1.0^{b}	114.2 ± 2.5^{b}	49.0 ± 1.2^{b}	121.2 ± 1.6^{a}	7.8 ± 0.9^{a}
12 months									
URS	88	115.9 ± 1.6^{c}	121.3 ± 1.8^{c}	34.8 ± 2.1^{b}	36.4 ± 1.2^{c}	130.5 ± 6.0^{c}	57.3 ± 6.6^{d}	155.4 ± 3.0^{d}	10.0 ± 0.6^{c}
UBS	61	116.1 ± 0.4^{c}	121.3 ± 0.8^{c}	34.8 ± 1.0^{b}	36.1 ± 0.9^{c}	132.8 ± 0.5^{c}	57.9 ± 3.8^{d}	155.1 ± 6.0^{d}	9.8 ± 0.6^{c}
H	52	117.8 ± 3.2^{c}	124.8 ± 2.6^{d}	34.6 ± 1.1^{b}	37.1 ± 3.2^{c}	132.4 ± 4.3^{c}	58.8 ± 4.1^{d}	156.2 ± 3.4^{d}	10.4 ± 1.0^{cd}
1/2URS1/2M	66	113.7 ± 1.3^{c}	119.9 ± 1.4^{c}	38.1 ± 1.9^{c}	38.7 ± 0.4^{cd}	131.8 ± 4.5^{c}	55.6 ± 3.4^{c}	159.6 ± 4.0^{d}	12.3 ± 1.2^{d}
1/4URS1/4M1/2H	52	115.3 ± 2.4^{c}	121.1 ± 1.8^{c}	34.6 ± 1.9^{b}	36.6 ± 2.4^{c}	131.2 ± 3.4^{c}	57.6 ± 5.0^{d}	156.2 ± 3.8^{d}	10.8 ± 0.9^{cd}
1/4URS3/4M	44	113.4 ± 1.4^{c}	119.1 ± 1.0^{c}	38.8 ± 1.1^{c}	40.1 ± 1.8^{d}	134.2 ± 4.0^{d}	56.3 ± 3.0^{c}	161.2 ± 2.7^{d}	12.6 ± 0.5^{d}
1/2UBS1/2NR	31	116.1 ± 0.4^{c}	120.6 ± 0.2^{c}	34.2 ± 0.9^{b}	36.1 ± 0.4^{c}	134.7 ± 0.2^{d}	53.9 ± 0.4^{c}	150.6 ± 1.2^{c}	9.3 ± 0.6^{c}
1/4UBS1/4NR1/2H	46	116.4 ± 1.7^{c}	122.3 ± 2.8^{c}	35.3 ± 1.8^{b}	37.6 ± 0.9^{c}	132.3 ± 2.9^{c}	58.3 ± 1.4^{d}	159.7 ± 0.9^{d}	9.3 ± 0.4^{c}
1/4UBS3/4NR	51	116.6 ± 0.9^{c}	122.0 ± 1.1^{c}	35.1 ± 1.0^{b}	37.4 ± 0.9^{c}	133.6 ± 1.2^{d}	57.9 ± 1.0^{d}	159.5 ± 1.0^{d}	9.5 ± 0.9^{c}

Note: different letters – see Table 1.

The purebred replacement heifers of Ukrainian Black-Spotted dairy breed were not inferior to the crossbred peers and the body measurements of replacement heifers ranged insignificantly depending on genotype, without significant difference. The crossbred heifers of genotypes 1/2UBS1/2NR, 1/4UBS1/4NR1/2H and 1/4UBS3/4NR are compact and proportionate, and have satisfactory categories of fatness when given a substantial and complete diet.

In the analyzed herd, the youngest heifers inseminated for the first time were those of genotypes 1/2URS1/2M and 1/4URS3/4M: at the age of 12.8–13.1 months ($P < 0.01–0.001$) with the live weight of 397.7–405.5 kg ($P < 0.05$). The heifers from Holstein and Norwegian Red sires were fertilized at the age of 15.2–16.3 months, 2.5–3.2 months later than their peers of previous genotypes. Their average live weight was 372.8–382.1 kg. Back crossing of crossbred Montbeliard bred heifers with Holstein bulls resulted in the replacement heifers that were inseminated at 15.5 months, having the live weight of 387.4 kg (Table 4).

Table 4
Timing of insemination of the replacement heifers and first calving of bred heifers of different breeds and genotypes (x ± SD)

Breed/Genotype	n	Fertile insemination			Calving		
		age, months	live weight, kg	height, cm	age, months	live weight, kg	height, cm
URS	88	15.2 ± 0.7^b	379.1 ± 8.2^a	116.9 ± 1.0^{ab}	24.7 ± 0.2^b	558.6 ± 9.2^b	136.8 ± 0.5^b
UBS	61	15.8 ± 0.4^b	380.6 ± 4.2^a	117.8 ± 0.8^b	25.3 ± 0.1^b	523.9 ± 10.1^a	137.2 ± 0.4^b
H	52	16.3 ± 0.4^b	372.8 ± 3.2^a	118.6 ± 0.9^b	25.8 ± 0.2^b	553.7 ± 9.1^b	137.6 ± 0.5^b
1/2URS1/2M	66	13.1 ± 0.2^a	397.7 ± 6.1^b	115.6 ± 0.3^a	22.6 ± 0.1^a	598.4 ± 7.8^c	129.3 ± 0.7^a
1/4URS1/4M1/2H	52	15.5 ± 0.1^b	387.4 ± 2.8^{ab}	118.2 ± 0.9^b	24.9 ± 0.1^b	572.4 ± 4.9^b	132.8 ± 0.5^{ab}
1/4URS3/4M	44	12.8 ± 0.1^a	405.5 ± 7.5^b	115.1 ± 0.5^a	22.3 ± 0.1^a	605.3 ± 5.1^c	128.9 ± 0.9^a
1/2UBS1/2NR	31	15.9 ± 0.2^b	377.7 ± 5.6^a	118.1 ± 0.8^b	25.4 ± 0.3^b	532.2 ± 9.2^a	137.8 ± 1.0^b
1/4UBS1/4NR1/2H	46	15.8 ± 0.4^b	376.4 ± 4.2^a	118.3 ± 0.9^b	25.3 ± 0.4^b	529.8 ± 8.1^a	137.7 ± 1.0^b
1/4UBS3/4NR	51	15.7 ± 0.4^b	382.1 ± 8.1^a	118.6 ± 0.9^b	25.2 ± 0.5^b	567.3 ± 11.2^b	137.9 ± 1.0^b

Note: different letters – see Table 1.

The bred heifers with partial inheritance of Montbeliard breed had first calving at the age of 22.3–24.9 months ($P < 0.001$). The live weight of the bred heifers reached 598.4–605.3 kg ($P < 0.001$). The infusion of Montbeliard blood caused higher intensity of growth in the replacement heifers, shorter raising period of younger age of first insemination and labor of the bred heifers.

Live weight of the replacement heifers that resulted from mating the Ukrainian Red-Spotted and Black-Spotted cows to Holstein sires at the time of first insemination ranged 379.1–380.6 kg at the age of 15.2–15.8 months, which accounted for 70% of the live weight of full-age cow [a cow in the period from the 3rd until 6th labor], and is an optimal indicator of herd reproduction. The first calving in those groups occurred at the age of 24.7–25.3 months, when the live weight of the bred heifers was 523.9–558.6 kg. The age of insemination and calving and the live weight of animals from Norwegian Red sires were close to the group of bred heifers from Holstein sires.

The period of raising cows (24–26 months) is usually the most favorable, both from economical and selection-breeding perspectives: capital investments are returned sooner; production expenses (feeding, labour force) decrease; the number of heifers needed for the support of herd size decreases, and genetic significance of the herd accumulates at higher rates.

In the conditions of farms, we studied correlation coefficients between the age of 1st insemination of cows and milk yield and amount of fat and protein in milk. According to the correlation coefficients, we determined that after increase in the age of 1st insemination and 1st calving, milk productivity of the cows decreased. It ranged 0.021 to 0.064 among the bred heifers of various genotypes and breeds. We observed an insignificant direct effect of the mentioned factors on the concentrations of fat and protein in milk ($r = 0.018$ to 0.064). The influence of age of animals during their 1st insemination on milk yield was 7.11% to 11.42%, and 5.44–6.89 on content of fat in milk, and 8.01–12.21% on amount of protein in milk.

First insemination of the heifers at older age did not produce highly productive cows. This indicates a possibility of using the data of relative variability for the formation of economically beneficial features in animals during their optimal development. That is why the influence of the age of 1st insemination and 1st calving of cows on dairy productivity should be taken into account for beneficial dairy livestock farming, and cows with optimal values of those parameters should be bred.

The conducted correlation analysis confirmed the presence of the determined relationships between the physiological factors and cow productivity, taking which into account would enhance the efficiency of its further selection-breeding improvement.

We determined presence of a positive dependency of milk yield on live weight during first insemination ($r = 0.308–0.510$). We observed an insignificant direct effect of the abovementioned factor on the content of fat and protein in milk ($r = 0.046–0.188$). Live weight during first insemination had the most appreciable effect on the milk yield of bred heifers – 12.07–15.01%, and somewhat lower effect on fat content in milk – 2.04–3.47%. Content of protein in milk was determined to be insignificantly affected by live weight of the bred heifers – from 0.83% to 1.20%.

The economic potential of dairy livestock farming depends on growing of replacement heifers of at least 400 kg live weight in shortest possible time. The highest level of dairy productivity of the bred heifers (over 8.0 thou kg of milk in 305 days of completed lactation) was reached in herds where the average daily increment of 0–12 month-old heifers reached the level of 820–850 g. The indicated parameters are a precondition for the formation of high-quality dairy herds, where the efficiency of milk production would be increased as a result of decrease in non-productive expenses for maintenance of replacement young and increase in net income from selling larger amounts of milk.

The course of calving in heifers is subject to many factors, the most significant being the physiological maturity, maturity of the pelvic bones, fetus size, which depends on feeding, maintenance conditions and preparation (Table 5).

Table 5
Percentages of complicated labour and stillbirth of cows mated to sires of different breeds (%)

Cross	n	Labour frequency			Stillbirth rates
		light (1–2 points)	mild (3 points)	difficult (4–5 points)	
URS	88	60.2	15.9	23.9	7.9
UBS	61	55.7	19.7	24.6	8.2
H	52	46.2	17.3	36.5	9.6
1/2URS1/2M	66	77.3	16.7	6.0	3.0
1/4URS1/4M1/2H	52	73.1	23.1	3.8	5.8
1/4URS3/4M	44	81.8	15.9	2.3	0.0
1/2UBS1/2NR	31	90.3	6.5	3.2	3.2
1/4UBS1/4NR1/2H	46	73.9	19.6	6.5	2.2
1/4UBS3/4NR	51	78.4	17.7	3.9	0.0

The pattern of interaction of those factors could be related to the dominating influence of calf or cow, but in many cases it is their combination. Obviously, we cannot disregard the influence of father on the development of a born animal, since half of the direct inheritance factors associated with its specifics belong particularly to him. It was confirmed that the factor of complicated calving and stillbirth of calves is inherent.

On their own and with assistance of 1–2 persons (light labor), 77.3–81.8% of the bred heifers of 1/2URS1/2M and 1/4URS3/4M genotypes gave birth. After back crossing of the crossbred dams of 1/2URS1/2M genotype with Holstein sires, the number of light deliveries decreased to

73.1%. The number of complicated calving and stillbirth rate among the crossbred bovines from Monbeliard sires did not exceed 6.0%. After insemination of the Ukrainian Red-Spotted and Black-Spotted dairy cows by Holstein bulls, the share of complicated labour increased from 6.5% to 36.5% and the stillbirth rate increased to 9.6%.

Cross with the Norwegian Red bulls resulted in the lowest stillbirth rate – to 3.2%. Crossbreeding of the animals of 1/2UBS1/2NR genotype with the Norwegian Red of Black-Spotted and Holstein bulls resulted in 73.9–90.3% light calving. The number of complicated delivery among the crossbreeds of 1/2UBS1/2NR and 1/4UBS3/4NR genotypes accounted for 3.2–3.9%. Further cross with the Norwegian Red sires reduced the stillbirth rate to zero. Crossbreeding can be effective for decreasing percentages of complicated labour and stillborns, which in turn would decrease the expenses they entail – treatment of consequences of complicated birth, the risk of decrease in the dairy productivity and longer calving interval because of complications during birth giving. However, it is necessary to make a careful selection of a breed, sire (it is advisable to take into account its assessment according to calving ease, especially when using Monbeliard breed) and analysis of breeding stock that are to be used in crossbreeding.

The reproductive ability of bred heifers was also evaluated according to the duration of calving interval, share of fertilized cows after first insemination, number of inseminations per one fertile (times), survival of bred heifers during the first lactation (%) (Table 6).

Table 6
Reproductive ability of bred heifers (x ± SD)

Breed / genotype	n	Duration of calving interval, days	Fertilized after first insemination, %	Number of inseminations per one fertile, times	Survival of bred heifers after 1st labour, %
URS	88	113 ± 6^b	29.1	3.37 ± 0.07^c	78.0
UBS	61	119 ± 7^b	26.9	3.55 ± 0.06^c	72.9
H	52	156 ± 8^c	18.9	4.49 ± 0.05^d	68.9
1/2URS1/2M	66	94 ± 2^a	46.2	2.11 ± 0.06^b	95.2
1/4URS1/4M1/2H	52	109 ± 4^b	31.2	3.18 ± 0.05^c	83.6
1/4URS3/4M	44	91 ± 5^a	48.0	2.06 ± 0.04^b	95.8
1/2UBS1/2NR	31	87 ± 6^a	53.4	1.86 ± 0.07^a	90.7
1/4UBS1/4NR1/2H	46	98 ± 3^{ab}	43.2	2.22 ± 0.06^b	82.4
1/4UBS3/4NR	51	85 ± 6^a	53.8	1.82 ± 0.07^a	93.0

Note: different letters – see Table 1.

Mean values of those parameters for cows mated to the Holstein bulls were as follows. Among the Ukrainian Red-Spotted dairy cows: the average age of the first calving was 24.7 ± 0.2 months, duration of the calving interval – 113 ± 6.1 days, impregnated after the first insemination – 29.1%, number of inseminations per one fertile – 3.37 ± 0.069 times, survival of bred heifers after first labour – 78.0%; Ukrainian Black-Spotted dairy breed: mean age of first calving – 25.3 ± 0.11 months, duration of calving interval – 119 ± 6.6 days, fertilized after first insemination – 26.9%, number of inseminations per one fertile – 3.55 ± 0.06 times, survival of bred heifers after first labor – 72.9%; Holstein breed: mean age of first calving – 25.8 ± 0.2 months, duration of calving interval – 156 ± 8.2 days, fertilized after first insemination – 18.9%, number of inseminations per one fertile – 4.49 ± 0.05 times, survival of bred heifers after labour – 68.9%.

The cows of 1/2URS1/2M genotype had the shortest calving interval (19 days), were observed to have increase in the share of cows fertilized after first insemination (+17.1% of the stock), decrease in the number of inseminations per one fertile (by 1.26 times), increase in the survival of bred heifers by 17.2%. As compared with the Ukrainian Red-Spotted dairy cows, back crossing of the cows of 1/2URS1/2M genotype with the Holstein sires resulted in the crossbred animals that had longer calving interval, higher rates of fertilization after first insemination and number of inseminations per one fertile, survival of stock after first lactation. However, from the crossbreeds of 1/4URS1/4M1/2H genotype – as compared with 1/2URS1/2M genotype – there were longer calving interval (+15 days), decrease in the share of fertilization after first insemination (–15%), higher number of inseminations per one fertile – by 1.07 times, and the survival of bred heifers after first lactation declined by 11.6%.

The crossbred firstborn cows of 1/2UBS1/2NR genotype had shorter period until first insemination (by 32 days), were observed to have increase in the share of cows impregnated after first insemination (53.4% of the stock), decrease in the number of inseminations per one fertile (by 1.69 times), and the survival of bred heifers was 90.7%. Despite the fact that the actual parameters of reproduction ability of bred heifers derived from various combinations of genotypes of parental pairs differed from the optimal towards increase – there are all reasons for stating that test cross of cows of Ukrainian Red-Spotted and Black-Spotted dairy breeds with Monbeliard and Norwegian Red sires can effectively decrease the percentages of complicated labour and stillbirth. This in turn would decrease the expenses for treatment of consequences of complicated labour and prevent decline in dairy productivity and longer calving interval due to delivery complications.

Table 7
Efficiency of test cross of dairy breeds (firstborns) (x ± SD)

Breed / genotype	n	Parameter: productivity over 305 days: actual milk yield, kg	fat content, %	protein content, %	cost of additional products per cow a year, UAH
URS	88	6323 ± 41^b	3.56 ± 0.05^a	3.18 ± 0.03^a	544.4
UBS	61	5966 ± 56^a	3.46 ± 0.05^a	3.12 ± 0.02^a	546.0
H	52	7388 ± 55^c	3.52 ± 0.04^a	3.07 ± 0.07^a	652.0
1/2URS1/2M	66	6388 ± 51^b	4.16 ± 0.03^c	3.35 ± 0.05^b	2220.4
1/4URS1/4M1/2H	52	6579 ± 81^b	3.57 ± 0.03^a	3.11 ± 0.09^a	1710.8
1/4URS3/4M	44	6409 ± 82^b	4.21 ± 0.07^c	3.34 ± 0.09^b	2526.5
1/2UBS1/2NR	31	6241 ± 74^b	4.11 ± 0.06^c	3.32 ± 0.02^b	1846.8
1/4UBS1/4NR1/2H	46	6580 ± 88^b	3.81 ± 0.05^b	3.18 ± 0.08^a	1512.9
1/4UBS3/4NR	51	6298 ± 72^b	4.23 ± 0.07^c	3.32 ± 0.03^b	2337.2

Note: different letters – see Table 1.

On average, in January, 2022, the extra-sort milk cost 10.73 UAH/kg, highest-rank – 10.61 UAH/kg, first-rank – 10.42 UAH/kg. The average price at the farm formed at the level of 10.58 UAH/kg. We used this specific parameter in estimations of the efficiency of milk production of the experimental cows.

Discussion

Breeding stock (cows) in dairy farming is the main way of production and therefore a correct practice first of all needs identifying the practical timing of using cows in herd and the level of annual culling (Sachuk et al., 2019; Slivinska et al., 2020; Mylostyvyi et al., 2021). Those aspects to a significant degree determine the tempos of growth of individuals and qualitative improvement of the stock, herd structure, sizes of capital investments for the formation of dam stock and efficiency of using cows. Intensity of replacement of herd is affected by infertility and temporary barrenness of dam stock. For those reasons, many farms lose a significant amount of the young and products, as well as money for maintenance of infertile animals (Roman et al., 2020). Losses in reproduction of livestock in a number of farms are still high – annually they lose offspring in the amount from 30–40% of breeding stock.

Raising replacement heifers is one of the main tasks of animal breeders. It is especially relevant because of the broad use of Holstein and Holsteinized cattle. Naturally, each breed of cattle has its standard of live weight, when reaching which an animal can realize its dairy productivity to the fullest, at the same time maintaining good health and condition.

Therefore, an intensive reproduction of highly productive herd implies adhering to a proper level of the zootechnical and veterinary practice of animal breeding (Gutyj et al., 2017, 2019; Borisenko et al., 2019; Slivinska et al., 2019). Currently, an extremely important measure is organizing reproduction of herds using purposeful raising of heifers by inseminating cows during early optimal periods taking into account their age, live weight, and breed. Intensive raising of replacement young of dairy breeds that become pregnant for the first time at the age of 24–27 months is effective from both selection breeding and economic perspectives. Insemination of well-developed heifers at an optimal time decreases costs for raising cows by 10–12%, because during the non-productive period of raising heifers, the expenses are 180–200 fodder units each month. Earlier mating of heifers also provides greater milk yields on average for each year of animal's life, prolonging of the period of their productive use and reproduction ability, decrease in expenses for their growing, and thus higher economic efficiency of using breeding stock. The cost price of the milk production is affected by costs for raising a cow during the period from birth to first calving. However, those costs are evenly distributed depending on the duration of farm use of cows in the herd. It has to be noted that the periods of productive longevity of young cows is one of the main criteria of effectiveness and profitable dairy livestock farming. The average duration of cow use below 2.5 lactations is unprofitable because mother cows are withdrawn from a herd before their daughters produce offspring (Roman et al., 2020).

Selling price of sold milk depends on productivity of cows, demand on domestic and foreign markets, and quality of dairy raw material that is being sold (Sachuk et al., 2019; Gubarenko, 2020; Borshch, 2021). The main factors increasing the profitability of commodities of animal husbandry from a farm of any type of ownership are increase in productivity of agricultural animals and quality of obtained raw material (Miciński & Pogorzelska, 2010; Robinson, 2010). Increasing fat content in milk by 0.1% above the main (basic fatness) is equivalent to 2.8% increase in the productivity of a cow herd. Prices for milk sold as the second-rank are 7%, and non-ranked 20% lower than the first-rank milk. Optimal dairy productivity of cows while having the lowest possible expenses for calving and costs is considered the main goal of dairy cattle breeding.

When analyzing the effectiveness of different schemes of cross breeding in herds of Ukrainian Red-Spotted and Black-Spotted dairy breeds, there was taken into account a number of zootechnical and economic parameters: expenses for raising of bred heifers, the so-called productive period, expenses for maintenance and feeding, profit from selling the products taking into account their qualitative compound, cost saving from survival of offspring and effective replacement of herd. On all the farms, the bred heifers produced raw milk with higher-than-basic concentrations of fat and protein.

When calculating actual milk yield in basic-fat milk, we determined extra products: amounting to 544.4 UAH per cow a year from the bred heifers of Ukrainian Black-Spotted dairy breed, and 2,220.4 UAH a year from the crossbreeds of 1/2URS1/2M genotype. After back crossing the cows and Holstein sires, benefits from the bred heifers decreased, first of all because of great expenses for the period of raising, lower reproduction quality and lower qualitative compound of milk. The cost of extra products accounted for 546.0 UAH per cow per year from the bred heifers of Ukrainian Red-Spotted breed, and 652.0 UAH from the Holsteins. Crossbreeding of the Ukrainian Black-Spotted dairy cows and black-breed Norwegian sires from crossbreeds of 1/2UBS1/2NR genotype resulted in 1,846.8 UAH per cow a year. Further upgrading with Norwegian Red breed resulted in the crossbreeds that produced extra products worth 2,337.2 UAH per cow a year.

Conclusion

The intensity of raising of heifers provided their development at the age of one year – depending on breed and genotype structure – at the level of 304.2–391.1 kg of live weight, 113.4–117.8 cm withers height and 150.6–161.2 cm of chest girth. Such parameters correspond to the parameters of live weight and the linear standards recommended for replacement heifers of the domestic breeds. At the same time, the crossbred heifers were seen to have higher level of relative "maturity", compared with the peers from Holsteins.

The highest profit from extra products from 305 days of lactation was produced by the cows of genotypes 1/2URS1/2M, 1/4URS3/4M and 1/4UBS3/4NR. It has to be noted that the estimated parameters of price of extra basic products per cow give grounds to state the positive effect from crossbreeding with Montbeliard and Norwegian Red.

Complex selection-genetic evaluation of dairy breeds and crossbred genotypes has scientific significance in providing evidence of the efficiency of introduction of selection-breeding programs of straightbreeding and crossbreeding of populations of the domestic dairy breeds.

The studies presented in the paper received no financial support from private companies or private funds, are factual and cause no conflicts of interests.

The authors claim no conflict of interest.

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