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Effects of Heifer Age and Liveweight at the Final Stage of Puberty and the First Service Conception on Cow Productivity and Welfare

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Abstract—The effects of the optimal liveweight values for heifers at the final stage of puberty and the first service conception on the cow lifespan, milk yield, and welfare status over three lactations was estimated. The survey was performed with domestic Black-and-White mature cows ($n = 7171$) born at the farm enterprise, Belgorod oblast, in 2010–2014. The milk yield of 7746–8570 kg per cow per indicated period was recorded; the milk fat and protein contents comprised 3.82–3.81 and 3.37–3.30%, respectively. In order to improve the cow welfare, to increase the lifespan, and to produce 20 400–31 800 kg milk over three entire lactations, the insemination of 15–16-month-old heifers of no less than 412 kg liveweight and 17–18-month-old heifers of 426 kg liveweight, taking into account their 12-month weights of 327–347 kg and 316–344 kg, respectively, should be reasonable.

Keywords: Black-and-White breed, heifers, liveweight, milk yield, welfare

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INTRODUCTION

The modern intensive farming technologies include complex production techniques for breeding, rearing, feeding, and keeping the animals. A high level of production technology is focused on increasing a cow's genetic potential for production, including the intensive system of rearing heifers for herd reproduction. All the combined production factors ensure a high animal productive performance. A lack of one of the factors can affect the production technology chain and reduce the animal's productive lifespan.

The first-calf heifers introduced into the main herd of the modern dairy cows comprise 25–30%. In Great Britain, the first-calf heifers annually introduced into the dairy herds comprise 22–25% [1, 2]. In Spain, the surveys proved that 31.5% of first-calf-heifers were culled over the 50-day period of the first lactation [3, 4]. Compensation for the heifer's rearing costs usually begins in the second lactation period [5]. Therefore, it is important that the heifer being introduced into the main herd should have the ability to live more than two lactations. According to some research data, the early age at first calving affects the reproduction and welfare statuses [6]. However, other researches could not prove such a relationship [7, 8].

The young-stock replacement rearing technology should be used with consideration of the biological specificity and contribute to the adequate growth, development, and formation of traits ensuring high production, strong conformation, and productive

lifespan extension in cows. The optimum period of rearing is economically and genetically more profitable.

The advantages of a heifer's intensive growth are in the rapid return on the investments, the current cost reduction, the productive lifespan increase, the accelerating rates of genetic improvement in herds, and the decrease in the total amount of feed required for nutrition from birth through first calving. However, the survey data [9] showed that increasing the liveweight of prepubertal heifers caused decreasing the milk production in cows. Simultaneously, there is an opinion that the costs of heifer replacement rearing may be reduced due to the accelerated rates of rearing and the earlier ages at first calving [10]. The puberty onset is generally dependent on the heifer weight rather than its age. The sexual maturation occurs when heifers reach 40–50% of the mature cow weight, irrespective of the age.

The findings for the age and liveweight effects in the first-calf heifers being introduced into the herd are also contradictory. In addition, these results are generally obtained while investigating the effects of the heifer liveweight at the age at mating or at first calving on the cow's productive performance [11].

The effect of the liveweight in the postnatal period at the final stage of puberty has been studied taking into consideration the fact that the bovine sexual development referring to the physiological changes is

Table 1. Cow liveweight by age periods, milk yield, and service interval over the first lactation

Age at first service conception, months	n	Liveweight at the age of, kg			First lactation	
		12 months	at the first service conception	at the first calving	milk yield, kg	service interval, days
13–14	525	343 ± 1.0	393 ± 1.7	564 ± 2.1	7530 ± 51	140 ± 4
15–16	3038	335 ± 0.5***	412 ± 0.6***	563 ± 1.8	7916 ± 21***	156 ± 2***
17–18	2799	325 ± 0.5***	426 ± 0.6***	564 ± 0.9	7840 ± 22***	161 ± 2***
19–20	556	321 ± 1.3***	438 ± 1.2***	568 ± 1.5	7867 ± 48***	171 ± 5***
21–22	253	322 ± 1.9***	451 ± 1.9***	570 ± 2.3	7995 ± 73***	170 ± 8***

*** $P < 0.001$.

very active between the ages of 7–8 months and ended at 10–12 months of age [12–14].

In addition, the problem of rearing the heifer replacement is urgent, since a new dairy cattle population with a high genetic potential has been created in Russia with the use of Holstein cattle [15].

The objectives of the survey are to determine the optimal liveweights of heifers being reared at the final stage of puberty (12 months of age) and the first service conception in terms of their effects on a cow's lifespan, milk yield, and welfare over three lactations.

MATERIALS AND METHODS

The surveys were carried out with 7171 domestic Black-and-White mature cows born at the farm enterprise, Belgorod oblast, in 2010 to 2014. The cows were kept in a loose housing system. The average milk yield comprised 7746–8570 kg milk per cow in a herd over the lactation period; the milk mass fraction of fat and protein comprised 3.82–3.81 and 3.37–3.30%, respectively.

The animals were grouped depending on their age at the first service conception and the volume of milk production over the first lactation period. The grouped animal data on the liveweight at 12 months of age and its variation at the first service conception and first calving, the variation in the service intervals for the first lactation, the milk yields over their productive lifespan, the cow's longevity, and the variation in the age of culling were analyzed. The data analysis was performed with the Microsoft Excel program.

RESULTS AND DISCUSSION

The service conception rates for the animals at 13–14, 15–16, 17–18, 19–20, and 21–22 months of age comprised 7.3, 42.4, 39.0, 7.8, and 3.5%, respectively (Table 1). The liveweight of the 12-month-old animals conceived to insemination at 13–14 months of age was significantly heavier than that in the heifers of all the groups of the greater age, while it was significantly less at the first service conception. The cow liveweight at

first calving had no difference between the animals in terms of their ages at first service conception.

No significant difference in the milk yield between the grouped animals conceived to insemination at 15–22 months of age was recorded (7840–7995 kg milk). Whereas the milk yields of the animals of all these groups were significantly superior when compared to the milk yields of the cows conceived to first insemination at 13–14 months of age. However, the service interval in the animals inseminated at the youngest age (13–14 months) was significantly shorter by 16–31 days, which was the cause of the difference in the milk yield per lactation over the first lactation period.

The analysis of this indicator for the animals of different ages at first service conception was performed to answer the question about what liveweight the heifers at the final stage of puberty should be in order to achieve the target level of the milk yield over the first lactation (Table 2). It was determined that the animals inseminated at 13–14, 15–16, 17–18, 19–20, and 21–22 months of age with the liveweights of 353–361, 338–347, 329–344, 326–331, and 325–329 kg at 12 months of age, respectively, could produce 8100–11000 kg milk per first lactation.

It should be noted that the liveweights in the 12-month-old heifers inseminated at 17–22 months of age (according to the appropriate grading categories for the first-lactation milk yield) were of the same range. Decreasing the rate to raise the heifers by 12 months of age relative to the reported values at their insemination at 13–16 months of age resulted in *over-keeping* the heifers up to their effective insemination time.

The least variation in the liveweight at 12 months of age according to the age-grading categories for the service conception rates, comprising 6.7, 7.9, and 9.2–9.3% was recorded in the heifers inseminated at 13–14, 15–16, and 17–22 months of age, respectively. In addition, less variation was indicated in the liveweight of heifers at 12 months of age when compared to the other levels of the milk yield (excluding the heifer effectively inseminated at 19–22 months of age),

Table 2. Twelve-month-old heifer liveweights in relation to different ages at first service conception

Milk yield over the first lactation period, thousand kg	Age at the first service conception				
	13–14 (<i>n</i> = 525)	15–16 (<i>n</i> = 3038)	17–18 (<i>n</i> = 2799)	19–20 (<i>n</i> = 556)	21–22 (<i>n</i> = 253)
5.1–6.0	339 ± 3.1	327 ± 1.3	316 ± 1.1	317 ± 4.3	313 ± 3.9
6.1–7.0	346 ± 1.9*	328 ± 1.0	316 ± 1.0	318 ± 2.6	316 ± 5.3
7.1–8.0	349 ± 1.8*	334 ± 0.8***	323 ± 1.1***	319 ± 2.3	319 ± 3.1
8.1–9.0	353 ± 1.9***	338 ± 1.0***	329 ± 1.6***	326 ± 2.7	325 ± 3.9*
9.1–10.0	361 ± 4.0***	343 ± 2.1***	330 ± 3.1***	334 ± 4.6*	329 ± 7.1
10.1–11.0	360 ± 6.9*	347 ± 3.6***	344 ± 4.6***	331 ± 11.7	325 ± 5.5

* *P* < 0.05; *** *P* < 0.001.**Table 3.** Variability in liveweight of cows at 12 months of age

Milk yield over the first lactation period, thousand kg	Age at the first service conception				
	13–14 (<i>n</i> = 525)	15–16 (<i>n</i> = 3038)	17–18 (<i>n</i> = 2799)	19–20 (<i>n</i> = 556)	21–22 (<i>n</i> = 253)
5.1–6.0	6.5	7.9	10.5	10.6	7.0
6.1–7.0	6.6	8.9	9.7	10.8	13.2
7.1–8.0	7.0	7.4	8.6	9.1	9.1
8.1–9.0	6.0	7.2	8.4	9.1	8.3
9.1–10.0	6.7	7.7	9.1	7.5	8.6
10.1–11.0	5.8	5.4	5.0	9.2	3.7

Table 4. Cow lifespan, months

Milk yield over the first lactation period, thousand kg	Age at the first service conception				
	13–14	15–16	17–18	19–20	21–22
5.1–6.0	56 ± 3.0	61 ± 0.9	70 ± 0.7	65 ± 2.0	71 ± 3.8
6.1–7.0	56 ± 1.7	62 ± 0.6	65 ± 0.7	61 ± 1.2	64 ± 2.1
7.1–8.0	50 ± 1.1***	60 ± 0.6	63 ± 0.7	62 ± 1.3	64 ± 1.8
8.1–9.0	51 ± 1.8*	56 ± 0.6	59 ± 0.9	60 ± 1.5	63 ± 1.4
9.1–10.0	40 ± 0.6**	54 ± 1.2	60 ± 1.8	57 ± 2.3	62 ± 3.6
10.1–11.0	37 ± 1.1***	60 ± 3.0	64 ± 2.8	46 ± 1.9	53 ± 3.9

* *P* < 0.05; ** *P* < 0.01; *** *P* < 0.001.

which might be caused by the low animal count in the grading group, *n* = 6 (Table 3).

It was ascertained that the heifers reared in the intensive farming systems and inseminated at 13–14 months of age were not generally inferior to the animals raised in the less intensive systems and inseminated at 15–22 months of age in respect to value for the first-lactation milk yield at the shorter service interval. The heifers inseminated at 13–14 months of age with liveweight of 339–360 kg had less longevity by 12 months of age at all the levels of the first-lactation milk yield. It was strongly expressed in the heifers with the milk yield of 7100 kg (Table 4).

The milk production value over three lactations is of great importance, since a cycle consisting of four calving events at three lactations is supposed, which is optimally required for the herd's basic reproduction. The total milk production over three lactations in the first grading category from 5100 to 10000 kg milk in the cows of different ages at the first service conception had no significant difference. In case of the first-lactation milk yield of 10100–11000 kg in the cows conceived to first insemination at 15–18 months of age, the total milk production was considerably higher in these cows than that in the cows inseminated earlier (at 13–14 months of age) or later (at 19–22 months of age) (Table 5).

Table 5. Cow milk yields over three lactation periods, thousand kg

Milk yield over the first lactation period, thousand kg	Age at the first service conception				
	13–14 (<i>n</i> = 525)	15–16 (<i>n</i> = 3038)	17–18 (<i>n</i> = 2799)	19–20 (<i>n</i> = 556)	21–22 (<i>n</i> = 253)
5.1–6.0	20.4 ± 1.7	20.6 ± 0.6	20.4 ± 0.4	21.1 ± 1.6	20.4 ± 2.4
6.1–7.0	22.7 ± 0.9	22.4 ± 0.4	21.7 ± 0.4	22.5 ± 0.8	22.7 ± 1.4
7.1–8.0	25.0 ± 0.6	24.5 ± 0.4	23.8 ± 0.5	24.2 ± 0.9	24.6 ± 1.2
8.1–9.0	26.7 ± 0.9	26.6 ± 0.5	25.8 ± 0.6	26.1 ± 1.0	26.1 ± 0.9
9.1–10.0	26.5 ± 0.8	28.4 ± 0.9	27.7 ± 1.2	28.5 ± 1.4	29.5 ± 2.7
10.1–11.0	24.1 ± 3.9	31.8 ± 2.4*	29.3 ± 2.2*	20.8 ± 1.8	20.5 ± 3.2

* *P* < 0.05.**Table 6.** Welfare of cows in the third lactation period in relation to that in the first lactation period, %

Milk yield over the first lactation period, thousand kg	Age at the first service conception				
	13–14 (<i>n</i> = 525)	15–16 (<i>n</i> = 3038)	17–18 (<i>n</i> = 2799)	19–20 (<i>n</i> = 556)	21–22 (<i>n</i> = 253)
5.1–6.0	49	49	62	52	53
6.1–7.0	47	47	48	36	41
7.1–8.0	38	38	40	36	39
8.1–9.0	25	25	26	30	27
9.1–10.0	21	21	28	10	25
10.1–11.0	19	19	29	0	0

However, all the cows introduced into the main herd live for only three lactations. At present, the average dairy cow age is at the level of 2.6–2.8 calving events. The problem for cow welfare over three lactations becomes even more complex with the cow first-lactation milk yield of 7100 kg. It is expressed more negatively in the cows effectively inseminated before 17 months of age and after 18 months of age. In addition, the latter cows with the first-lactation milk yield of 10100–11000 kg do not survive the third lactation (Table 6). For this reason, their total milk production is lower (20800–20500 kg) (Table 5).

CONCLUSIONS

Therefore, inseminating the 15–16-month-old heifers of no less than 412 kg liveweight and the 17–18-month-old heifers of 426 kg liveweight, taking into account their 12-month weights of 327–347 kg and 316–344 kg, respectively, should be reasonable, in order to improve the Black-and-White cow's welfare in the intensive farming system and to produce 20 400–31 800 kg milk over three entire lactations.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interests. The authors declare that they have no conflict of interest.

Statement on the welfare of animals. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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