Bulgarian Journal of Agricultural Science, 26 (No 6) 2020, 1297–1304

Biological features of the formation of cattle in the prenatal period of ontogeny and subsequent dairy production

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Abstract

Chernenko, O. M., Lieshchova, M. O., Orishchuk, O. S., Chernenko, O. I., Zaiarko, O. I., Tsap, S. V., Bordunova, O. G. & Dutka, V. R. (2020). Biological features of the formation of cattle in the prenatal period of ontogeny and subsequent dairy production. *Bulg. J. Agric. Sci., 26 (6)*, 1297–1304

The results of the study of the length of the prenatal period of ontogenesis of 51 Ukrainian Red Dairy breed tribal cows are presented, and the relationship of this trait with the rate of growth of the organism in the postnatal period (at birth, at 6, 12 and 18 months) and dairy productivity for the first lactation are investigated. Also, at different stages of the prenatal period of ontogeny the dynamics of the mass of 66 fetus and some parenchymatous organs (liver, spleen, thymus) selected by anatomical preparation are determined. The aim of the research was to establish the possibility of predicting dairy productivity of Ukrainian Red Dairy breed cows over the length of the prenatal period and the effect of this period on the postnatal growth rate of the organism, and also to ascertain the existence of a regularity between the increase in fetus mass and the development of certain hemopoiesis organs at different stages of prenatal development. Laboratory animals were divided into three groups, depending on length of their prenatal period: less than 277 days-reduced (group I), 277–283 – medium (group II) and more than 283 days – extended period (group III). For 305 days of the first lactation, the advantage over milk yield, milk fat yield and milk protein belongs to animals with shortened duration of the prenatal period of ontogenesis in comparison with contemporaries who had an extended period with a statistically significant difference ($P < 0.05$). A further study in the short term may be a study of the relationship between the duration of the prenatal period and the rate of fetal growth with the subsequent forming of the physique, and in the long term turning into the study of the relationship between the duration of the prenatal period and the rate of fetal growth with a duration of productive use and lifelong productivity.

Keywords: ontogeny; prenatal period; fetus mass; live; spleen; thymus; milk productivity of cows

Introduction

One of the important questions in selection process is the study of the potential production and biological features of animals, elaboration of their accelerated assessment. The forecasting of pedigree and economically useful traits is necessary to solve these questions (Bach, 2011). Most researches are brought to the study of the relations between mass and examples of exterior of the animalsin the early phases of ontogeny with following productivity and reproductive capability. The data is given about the relations of the average daily weight gain from birth to the first calving with the yield of cows. In particular, it is reported (Yin et al., 2018) that less dairy cows grow from calves when too much of population growth hap-

pens. The reason is excessive feeding, leading to the formation and deposition of fat in the body, which changes the type of build in cattle in the direction of meaty build. The same opinion is shared by other researchers (Zanton et al., 2005). According to their data, those cows of Holstein breed, whose body weight at the first calving was not more than 477–550 kg, were characterized by the best indicators of milk yield and protein yield per 100 kg of own weight. It is established (Van De Stroet et al., 2016) that tall calves at birth are formed into cows that are able to consume a large amount of bulky fodder. More milk without significant strain on the body is received from them during the first lactation. This is achieved due to the good development of linear measurements of the axial and peripheral skeleton, the middle part of the trunk and chest, as well as the internal organs, but not due to obesity or excessive development of the musculature.

Another indication that can be used for early prognosis of productivity is the length of prenatal development of animals. It is reported that the shortcomings in feeding, the diseases and the daily operational loads on the mother's body are also reflected in the development of the fetus – its mass, health, duration of prenatal development and vitality (Wolfenson et al., 2000; Hansen et al., 2002; Tao et al., 2012; Merlot et al., 2017; Chernenko et al., 2017; Chernenko et al., 2018). It is established (Tomasek et al., 2017) that the duration of prenatal development of the fetuses of Anglo-Saxon cattle is related to the month of insemination, the month of calving, the age of the mother and the sex of the fetus. The duration of pregnancy in cows inseminated in different months of the year was longer than that of the heifers throughout the year in different flocks ($P < 0.05$) and with insemination in different months of the year. The duration of the pregnancy was longer in cows and heifers, which were inseminated in the first months of the year than those that were inseminated in the last months of the year ($P < 0.05$). The duration of pregnancy in cows and heifers, which were inseminated in late autumn and winter, was longer than inseminated in spring and summer ($P < 0.05$). The prenatal development of the bull-calves was longer than the female calves ($P < 0.0001$). It is proved (Hordiychuk et al., 2017) that the Simmental breed with reduced and medium length of the prenatal period grew and developed better based on the indicators of absolute, average daily and relative growth spurs up to 6 months of age. The best embryonic growth rate was characterized by the heifers of the winter season of birth. The authors argue that the duration of the prenatal period of development of animals can influence to the age of the first insemination. Thus in heifers with an average duration of the prenatal development period (284.6 days) physiological maturity occurred at 18.1 months, whereas in peers with a reduced period (278.7 days) – at 18.6 months, and with an extended duration (293.1 days) – in 18.3 months. It is proved (Footeetal., 1959) that inbreeding does not have a significant effect on the duration of prenatal development of calves. More it depends on the sex of the fetus. Thus the Holstein bulls on average were born 5.92 pounds heavier and had 1.44 days longer prenatal development than the female calves. From the right horn of the uterus, heavier calves were obtained (by 1.78 pounds, $P < 0.05$) than from the left horn. But the effect of this factor on the duration of the prenatal period of fetal development was not confirmed.

It was found that the absolute increase in body weight at the beginning of embryo development is low, and then it increases significantly (Nešetřilová, 2018). The growth periods of the whole organism do not coincide with the growth periods of individual organs, since they do not cease growing simultaneously (Taher et al., 2010; Berg et al., 2010). The rate of growth and development of organs depends on their significance and functions in the life of the animal at certain stages of ontogenesis (Arora, 2011). In addition, the growth of the animal and the growth of its individual organs are influenced by numerous genetic and non-genetic factors. They manifest themselves both in the prenatal and postnatal periods of development (Ferrell, 1991; Schmidt et al., 2004; Copping, 2017). General patterns for the development of hematopoiesis organs and immune defense is their early establishment in embryogenesis, the achievement of almost complete functional maturity by the time of birth. This is evidenced by the presence in the majority of peripheral lymphoid organs of reactive structures (lymphatic nodules with centers of reproduction) and early age involution in the postnatal period of ontogeny (Sapin, 2006; Olearo et al., 2012; Balogh, 2010; Cupedo et al., 2010; Sayed et al., 2010; Lane et al., 2010; Balogh, 2011; Islam et al., 2018; Gavrilin et al., 2018). Along with the general patterns there are particular patterns of age-related changes in morphometric parameters typical for each organ. This is due, above all, to the transformation of their tissue and cell relations, depending on the structural and functional characteristics of the organ. There is also a specificity of its interrelations with other organs, species of animals, biological and ecological features (Scammon, 1927). The total amount of blood in the body and its composition directly affect the synthesis of milk in the udders of cows (Kailasapathy, 2009). As the result in the context of our research it is of interest to clarify the relations between the overall development of fetuses and hemopoiesis organs at different stages of the prenatal period of ontogeny.

Biological features of the formation of the organism of cattle in the prenatal period of ontogeny, possibly, can make a difference in the selection process for predicting future dairy productivity. Meanwhile, the study of the relations between the length of prenatal development and dairy produc-

tivity was not conducted in cattle of the Ukrainian Red Dairy breed. It is extended in the central and southern regions of Ukraine. This breed was created on the basis of the maternal local breed called Red Steppe, which was crossed in different years with bulls-producers of Red Danish, Angler and Holstein breeds. Each of these breeds introduced its own specific genetic complexes into it. But outside the attention of researchers is the question of how this affected the biological features of prenatal development of the new breed organism because the original breeds differ in this feature. And also it is not studied how these features influence the performance of subsequent dairy productivity with the goal of its early prediction. In addition, it was found a gap as to whether the experimental justification for explaining the cause-effect relations between the different length of the prenatal period and the milk productivity of cows, which also represents scientific novelty in our studies.

The aim of the research is to find out the possibility of using the biological features of the length of the prenatal period as a method for the early prediction of milk productivity in cows of Ukrainian Red Dairy breed for the first lactation. It was also important to establish the effect of this trait on postnatal growth intensity and to reveal the regularity between the increase in fetal mass and the development of hemopoiesis organs at different stages of prenatal ontogenesis.

Material and Methods

Studies were carried out on 51 breeding cows of Ukrainian Red Dairy breed, which were peers and had the first completed lactation. Their mothers were inseminated in the first three months of the year. The experimental livestock belongs to the private agricultural enterprise "Chumaki" of the Dnepropetrovsk region. This is a well-known breeding plant in Ukraine which breeds cattle of Holstein breed, as well as Ukrainian Red Dairy breed, where it was produced. The experimental population was kept in a free-standing box-type mode with feeding on the feeding tables and milking in the milking hall with milking machine of "Carousel" type.

For the separation of animals into groups, a range of the frequency distribution of the variation series for the duration of the prenatal period of ontogeny was constructed. The number of classes in the range was calculated by the Sturgess formula. Cows were divided into three groups, based on the following principle of group formation. The largest numbers of animals were in the middle group (x±0.67SD). Animals with prenatal development less than this range were divided into a group with a shorter period, and their peers exceeding this range were grouped into an extended period group.

In the postnatal period of ontogeny the body weight of young animals was taken into account in subsequent age periods: at birth, at 6, 12 and 18 months. All the experimental cows had transponders. Milk yield of cows for the first lactation were determined automatically during milking at the milking machine «Carousel» using the system "DAIRYPLAN C21". The component composition of milk was determined during the 10 months of lactation. Milk was analyzed individually for each cow once a month in the middle decade on the analyzer "Ekomilkmilkanakam 98 2a".

Fetuses for research have been selected from Ukrainian Red Dairy cows after slaughter (for reasons unrelated to infectious and invasive diseases) in the conditions of meat processing enterprises of the city of Dnieper. The age of the fetuses was determined by weight, length of the body and the degree of development of the derivative skin (Studencov, 2000). Internal parenchymal organs – the liver, spleen and thymus were selected by anatomical preparation. The absolute mass of fetuses and organs was determined by weighing using the KERN-440-35A scaleaccurate within 0.001 g. 66 fetuses and their organs were examined in total.

The analysis of the experimental data was carried out with the help of Statastica 6.1. The data in the figures are presented as: mean value, mean value ± standard error, and mean value ± standard deviation.

Results

In cows with a shortened prenatal period of ontogeny (group I), its duration was in the range from 270 to 276 days, with an average (II group) – from 277 to 283 days, while with an extended period (group III) – from 284 to 290 days (Figure 1).

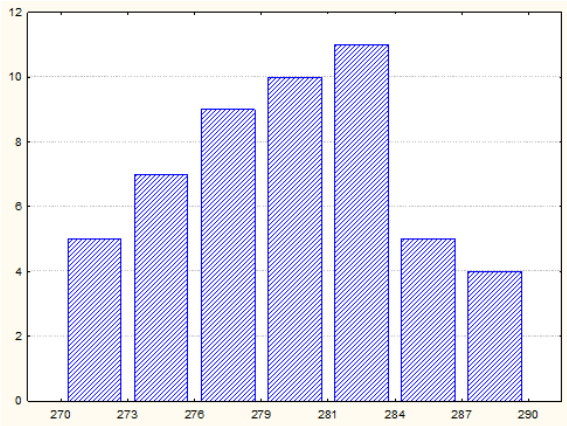

Fig. 1. Frequency distributions of the variation series for the duration of the prenatal period in cattle of the Ukrainian Red Dairy breed: (n=51)

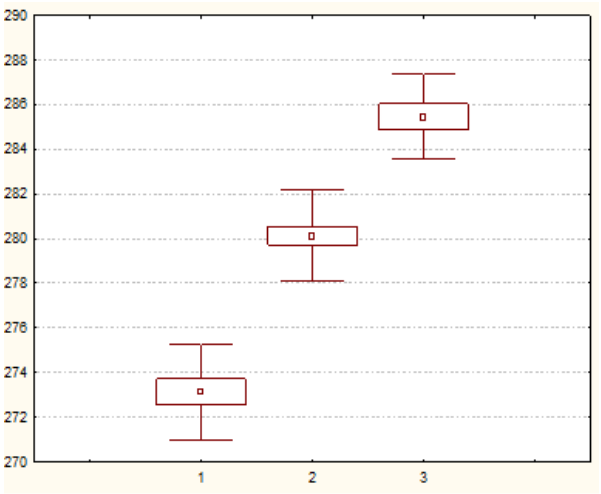

Fig. 2. Length of prenatal period of ontogeny (days) in experimental animals: 1 – shortened (n = 14); 2 –medium (n = 26); 3 – elongated (n = 11); Friedman ANOVA method

As our studies have shown, groups of animals varied differently in terms of length of the prenatal period (Figure 2), which reflected on their formation in the postnatal period of ontogeny (Figure 3).

The data given (Figure 3) shows that a statistically significant difference (P <0.05) over the live weight among the animal groups examined is observed at birth (Figure 3a) in favor of the calves with an extended prenatal period, and also at the age of 6 months (Figure 3b, 3c), but at this age it's in favor of the calves with a shortened and average prenatal period. After reaching the age of 12 and 18 months, the body weight of animals of different groups is gradually leveled and acquires statistically unreliable differences (Figure 3c, 3d).

Features of the formation of the organism in the early periods of ontogeny and the subsequent milk productivity are reflected in the data of Table 1.

Cows of the third group on milk yield for 305 days of the first lactation are inferior to those of group I. The difference is reliable and amounts to 600kg of milk. A similar dependence is observed for the yield of milk fat – 25.2 kg and milk

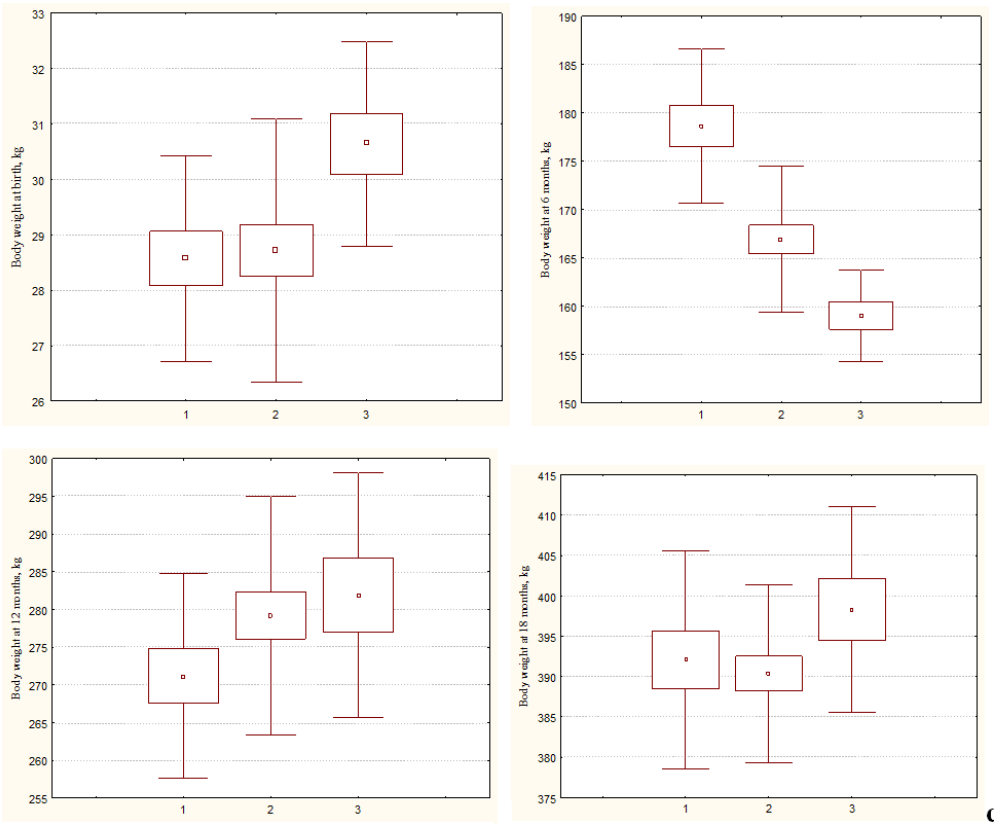

Fig. 3. Body weight at birth (a), at 6 months (b), at 12 months (c), at 18 months (d) in experimental animals with different length of the prenatal period of ontogeny: for notations see Figure 2

Table 1. Milk productivity of cows for the first lactation with different length of development in the prenatal period of ontogeny (x±SD)

Features	Groups of animals		
	I (n=14)	II (n=26)	III (n=11)
Annual yield for 305 days, kg	4465±551.8[a]	4157±601.9[a]	3865±360.2[b]
Content in milk: fat,%	3.81±0.20[c]	3.93±0.26[c]	3.75±0.24[c]
Protein,%	3.14±0.12[d]	3.12±0.11[d]	3.13±0.12[d]
Lactose,%	4.89±0.05[e]	4.88±0.08[e]	4.89±0.05[e]
Ash,%	0.66±0.02[f]	0.67±0.02[f]	0.67±0.02[f]
Dry matter,%	12.50±0,30[g]	12.60±0,35[g]	12.44±0,34[g]
Milk fat yield, kg	170.1±16.3[h]	163.4±29.0[h]	144.9±16.2[i]
Milk protein yield, kg	140.2±16.0[j]	129.7±20.1[j]	121.0±15.6[k]

Note: different Latin letters marked samples that differ significantly from group I (*P <0.05*) according to the results of the Tukey test

protein – 19.2 kg. Group II of animals occupied an intermediate position, significantly differing from group III peers in milk fat yield (P <0.05). The percentage of fat, protein, lactose, ash and dry matter in the milk group of animals was not significantly different (Table 1).

To explain the reasons for the higher milk productivity in cows that had a shortened and average duration of the prenatal period of ontogeny, we studied the relation between the formation of some internal organs and the mass of the fetus (Figure 4).

It has been established that up to a certain age and a certain mass of the fetus a clear pattern is observed: with increasing fetal mass, the mass of the organs also increases, which corresponds to the laws of growth and differentiation that are generally accepted in biology (Shmal'gauzen, 1984). In our studies the increase in fetal mass was invariably accompanied by a better development of hemopoiesis organs. But such a pattern is observed only until the end of the second third of the fetal period. In the further process of prenatal growth, beginning at the age of 7 months, which corresponds

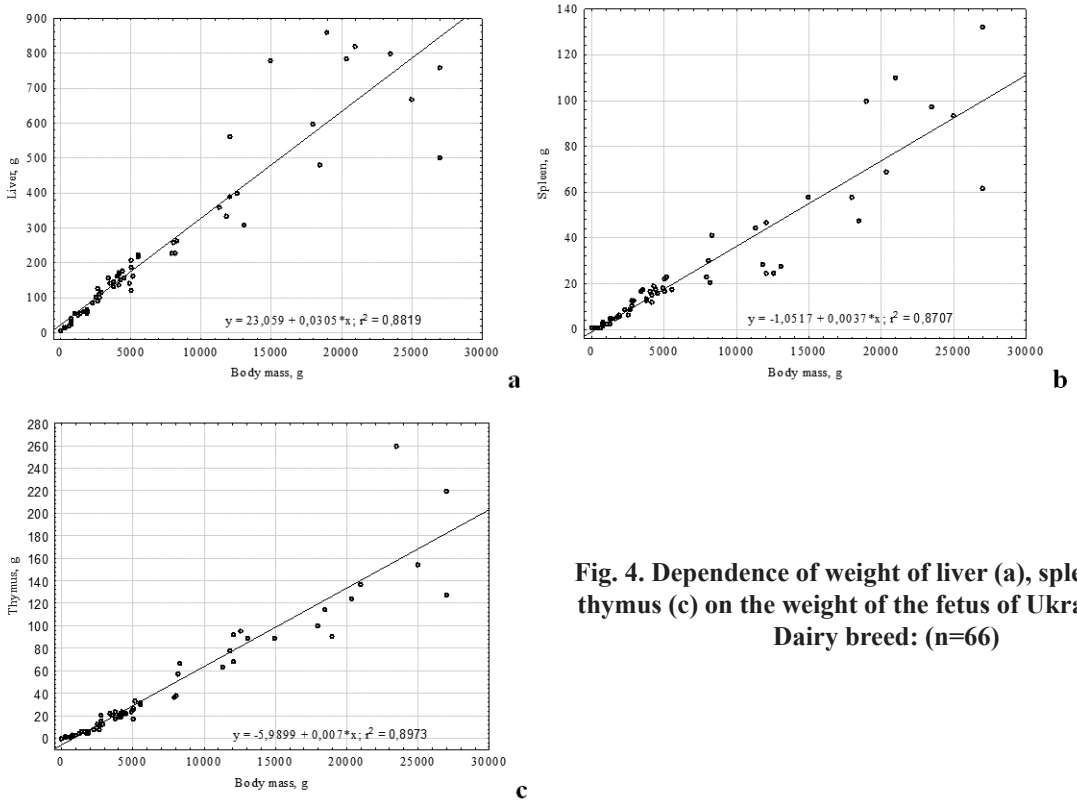

Fig. 4. Dependence of weight of liver (a), spleen (b) and thymus (c) on the weight of the fetus of Ukrainian Red Dairy breed: (n=66)

to 5–6 kg of weight (Studencov, 2000), this pattern is not observed in all fetuses, but starting from the 8th month old age, which corresponds to 12–20 kg of mass, we can observe the inverse relation between these two characteristics (see Figure 4). From which it follows that the largest fetuses at birth will not have maximally developed internal organs. At the same time this proves that in calves born with a smaller live mass, but within the limits of permissible deviations, with a shortened and middle period of prenatal development, internal organs did not receive worse development than their peers with an extended period of formation.

Discussion

Based upon studies conducted the scientists (Bir et al., 2018) have found that small calves with a smaller live mass at birth become more productive cows and have fewer cases of dystocia. Therefore, in their opinion, the calf's body weight at birth, and later also of cows, may be bigger than it is economically feasible. Also found (Yin et al., 2018) the influence of body weight at birth on the sickness rate of cows after their first calving with mastitis, diarrhea, respiratory diseases and hoof disease. It was established that heifers which had a bigger body weight at birth were more prone to disruption of the general metabolism and to the said diseases. The coefficient of heritability of body weight of calves at birth at the level of 0.47 is determined.

The influence of height in the hip joints of calves on the rate of growth in subsequent periods of ontogeny and the subsequent milk production was studied (VanDeStroet et al., 2016). It was determined that the calves, which were characterized by the average size of the measurement, were the most productive cows. The worst of them were cows, which at the youngest age had this measure at the smallest. In addition, they were characterized by less viability and more often than the others left the herd by the end of the first lactation. In calves born with higher hip joints no higher milk yield was observed for the first lactation, but they had higher viability and a lighter weight at a later productive age. From which we can conclude that not so much the absolute value of the mass of the body at birth is important for the viability of the animal, but more which of its components had led to that weight. This study emphasizes the importance of the development of the peripheral skeleton and internal organs that are simultaneously associated with its development, with an emphasis on the fact that there is a relationship between the development of organs and their function. Therefore, when selecting, it is important to give preference not just to smaller calves, but to those that have a body mass at birth within the limits allowed for each breed. At the same time, the scientists (Zubets et al., 1994) consider it necessary in every specific herd to establish a limit on the body weight of newborn calves obtained from well-developed, clinically healthy cows that have been properly trained prior to calving. Deviations from extreme indicators are proposed to be considered a violation in the development of newborns. Limits of permissible body mass deviations of newborns are suggested to be a standard deviation of ±2SD from its mean value separately for original cows and separately for older cows.

In the process of breeding cattle, it became common to get larger cows and bulls-producers. As a result, the offspring more often began to appear larger than the average. This began to lead to more severe calving, and cash investments in feeding calves that are larger at birth, as well as larger cows, ceased to be adequately paid off the by the products received from them. In this regard, scientists economically modeled how the payback of the ever increasing body weight of cows and calves, obtained by profit from the sale of products for the next 15 years, will be realized in the future. It was assumed that calves with smaller weight at birth were also obtained from lighter cows, although there was no linear dependence between them. The model assumed the same indices of dystocia for large and small cows. The results showed that the body weight of the cow can be greater than it is economically feasible. Smaller cows received more profit, so there is a need to selectively reduce the body weight of cows within acceptable tolerances (Bir et al., 2018).

The existence of a genetic correlation between calf mass at birth, the duration of its prenatal development and the intensity of prenatal growth is established (Bourdon et al., 1982). In particular, the correlation between the duration of the prenatal period and the weight of the calf at birth was 0.37 for bulls and 0.35 for heifers. It is proved that faster growing fetuses might get delivered before the average due date. Based on the evaluation of the recurrence, it was concluded that, based on a smaller calf mass at birth, which is still within the tolerance limits, it is possible to gradually reduce the timing of pregnancy in cows and to receive calves that later become mature for reproduction earlier.

Thus, the duration of the prenatal period, the live weight and general development of the heifer organism in the postnatal period have hereditary conditioning, affect the viability and productivity of cows. Analysis of logistic regression and survival of mixed effects for dichotomous variables and a model of mixed effects for continuous ones shows that different heights of heifers in early ontogenesis (from birth to 2 months) can be a breeding feature in the selection process (Bach, 2011). And this, as we have already noted, is somehow connected with the duration of prenatal development of the organism, focusing on which there is also the possibility

for an early prognosis of future milk productivity in cows. In our studies, prenatal precocity continued to be detected in the first six months of life of the postnatal period. This is important from the point of view that in this interval of ontogenesis there is a more intensive formation of muscle tissue (Shmal'gauzen, 1984). This in turn, in our opinion, can explain to some extent the advantages of forming a higher milk productivity of the cows of first group.

A further study in the short term may be the study of the relationship between the duration of the prenatal period and the intensity of fetal growth with the subsequent constitution of the constitution, and in the long run the study of the relationship between the duration of the prenatal period and the intensity of fetal growth with a duration of productive use and lifelong productivity. This will characterize the operational qualities of animals, which are of paramount importance for the practice of dairy cattle breeding.

Conclusions

The duration of the prenatal development period affects the live weight of calves at birth, the rate of growth of their body in the postnatal period and the level of subsequent dairy productivity. With a shortened (up to 277 days) and an average (277–283 days) prenatal period, Ukrainian Red Dairy breeds differ in higher growth rates from birth to 6 months of age ($P < 0.05$). The prenatal periods of the Ukrainian Red Dairy breed are characterized by a higher body growth rate and an average from birth to 6 months of age leveling off by body weight with the rest of the peers after reaching the age of 18 months. Biological features of the prenatal period of ontogeny may be used for early prognosis of subsequent milk production. Replacement heifers with reduced and average duration of the prenatal period and a smaller body weight at birth, which is within acceptable tolerances, are formed into more milk abundant cows. Compared with peers with an extended prenatal period (284 days or more), they have a higher yield of milk fat of milk protein, not differing in the component composition of milk within 305 days of the first lactation. In heifers with less body weight at birth, internal organs of hematopoiesis (liver, spleen and thymus) didn't receive worse somatic development than their larger contemporaries.

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Received: July, 18, 2019; *Accepted:* September, 11, 2019; *Published:* December, 31, 2020