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Research Article

Potential for Health and Productive Life Span of Dairy Cows is Formed in the Early Periods of Ontogenesis: A Concept from the Standpoint of System Biology

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Abstract

Based on the results of the analysis of production data on the survival rate in the population of Black-and-White cows, it was found that the average Productive Life Span (PLS) significantly depends on the value of the relative retirement during first lactation ($P<0.001$), i.e., this parameter can be used as a predictor of PLS in representative samples. The formation of viability potential begins already during the maturation of oocytes and in the process of embryo development, therefore, the data obtained indicate the need to organize monitoring of the physiological state of dairy herd and to study the influence of epigenetic factors on the viability of highly productive cows.

Keywords: Highly productive cows; dairy herd; viability; epigenetic factors; productive life span; physiological monitoring

Introduction

The main reason for the life longevity in populations of highly productive cows is the lack of effective viability tests to include them in breeding indices and to monitor this trait when using intensive technologies. Studies conducted in recent decades have shown that possible candidates for the role of tests for predicting survival parameters should not be sought in terms of physiological homeostasis, they are more likely to be found in the field of action of constitutional and epigenetic factors of longevity. The aim of this work was to study the age dynamics of survival rates in a large population of dairy cows using system biology methods.

Material and Methods

Data on the number of Black-and-White cows for successive lactations in 15 production-territorial divisions (breeding centers, separate districts) of the Leningrad oblast in the period 1985-1991 were used as primary material. Time series averaged over five successive years in each subpopulation were analyzed in the Excell by numerically integrating the differential equation $y(t)=dN(t)/[dt*N(t)]$, as an analytical form of the empirical Gompertz function $y(t)=B*exp(c t)$, where t is the number of lactation, N(t) is the number of cows in the cohort (in the group of individuals of the same year of birth) at in the current lactation, y(t) is the probability of withdrawal from the cohort (relative retirement $\Delta N/N$ for 305 d. lactation) for the current lactation according to the sum of natural causes. The obtained series of cow's number in cohorts were used to estimate the average productive life span T in the studied subpopulation and in the whole population [1,2].

Results and Discussion

The data analysis for the entire studied population revealed a significant dependence of the average PLS (T, number of lactations) on the reciprocal value of the relative retirement during first lactation:

T = 1.2 + 0.26 (1/y1) ($R^2 = 0.99$, $P<0.001$)

This relationship can be interpreted as evidence that the average PLS in representative sample of cows can be predicted from the value of relative retirement at the first lactation (or on average of the first and second lactations, since the rate of increase in the value of y(t) is minimal during this period). In other words, the value of 1/y1 can be used as a predictor of the quantitative trait of viability T, which was formed in cows during the time preceding the achievement the age of reproductive maturity. When analyzing the results obtained, it was also revealed the correlation between the values of the parameters B and c in the Gompertz function y(t)=B*exp(c t) constructed from the empirical data. To explain this correlation, a computational model was studied, in which 15 subpopulations were homogeneous in parameter c, and most of them were heterogeneous in parameter B, i.e., this part of the subpopulations had different values of this parameter, which should have led to a decrease in the c parameter for the entire model population. The results of the performed series of calculations confirmed the correctness of the assumption made, since the regression line in the model population coincided with the trend line identified in the real population [2]. This result can be considered as an additional confirmation that the average PLS of cows significantly depends on the value of the relative retirement during first lactation, with the same value of the c parameter (or with its slight variation). The study showed that PLS for cows is determined to a certain extent by the level of viability (general background age-dependent resistance to damaging effects, i.e., constitutive resistance), which is formed during periods of pre- and postnatal ontogenesis before the first lactation; the higher this the initial level, the greater the chances for this group of individuals to have a long PLS. The advantage of the conducted retrospective analysis is that a large array of empirical data was used, the studied population was genetically homogeneous, and the patterns of the number of cows for successive lactations were stable over a number of years, which is fundamentally important, since age patterns of retirement are often variable. Many studies have shown that the incidence of age-related diseases depends on conditions during periods of early ontogenesis, i.e., the formation of viability potential critically depends on the conditions of embryonic development [3-7]. In cows, this time coincides with the transition period (in the first third of lactation), so it is necessary to find ways to increase the level of “primary health” in the offspring [8]. The totality of accumulated data indicates that the level of viability and longevity potential in cows is the result of the interaction between the genome and epigenome, i.e., between genetic factors and epigenetic modifications that are fixed in response to the impact of endogenous and exogenous factors at the early stages of ontogenesis (before the start of the reproductive period). Therefore, possible candidates for the role of cow viability markers should not be sought in terms of physiological homeostasis; they are more likely to be found in the long-term constitutive and epigenetic factors.

Conclusion

The data analysis on survival parameters in a dairy population showed that PLS significantly depends on the value of the relative retirement during first lactation ($\Delta N1/N1$), so this parameter can be used as a predictor of the average PLS for a representative sample - a quantitative sign of viability, which is formed in cows in the periods preceding the age of reproductive maturity. In the light of these data, the need to organize physiological monitoring of a dairy herd and to identify epigenetic factors in the formation of viability potential in highly productive cows is actualized. In order to prolong the productive life and efficiency of the cow’s reproduction, it is necessary in addition to fighting diseases, to increase the initial level of health, i.e., functional reserves formed during maturation of oocytes, development of embryos, and during critical periods of postnatal ontogenesis.

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