Dynamics of variability of the animal heart rhythm and its correlation with economic parameters and age

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Abstract. For several years, strengthened state support caused a situation, when domestic livestock has reached the European level on many qualitative and quantitative parameters. At the same time, dairy cattle breeding remains one of the most problematic branches. Intense loads during economic use lead to a decrease in vital energy and functional and physiological reserves of the body. The problem of reducing the economic characteristics of cows with age is relevant. In this regard, many questions related to the need to preserve these functional reserves arise and the latter can be studied using non-invasive methods. One of such methods is cardiointervalometry of heart rate variability. The method allows evaluating the physiological state of the animal, which can be influenced by both exogenous and endogenous factors.

1 Introduction

The productivity of farm animals is one of the urgent problems of physiology, because it has a significant practical aspect.

There is information in the scientific literature that animals with high innate functional reserves are characterized by high milk productivity, stable lactation curve, and other useful economic characteristics.

This is due to the fact that the adaptive capacity of the animal's organism is a certain functional reserve, which is constantly consumed. Such reserves include energy, metabolic and information resources. Congenital reserves provide the initial power of adaptation mechanisms and are not the same in different animals.

The animal heart possesses the highest metabolic and energy resources, which is capable of providing a higher minute blood circulation at the same heart rate. As a result of this, the same cardiac output can provide greater oxygen delivery and utilization with less stress on regulatory systems, that is, it is characterized by relatively higher information resources.

The functional reserves of the cow's body can be measured using the method of heart rate variability according to R.M. Baevskiy [1].

The mathematical analysis of the heart rhythm is used as a new method for studying the regulatory processes occurring in the animal's body.

This method makes possible to explore and evaluate the mechanisms of regulation of the cardiovascular system, as well as the tension of regulatory systems, to identify the activity of the sympathetic and parasympathetic divisions of the autonomic nervous system, autonomic regulation index, autonomic rhythm parameter, the indicator of the adequacy of regulation processes, that is very important to identify the functional capabilities of the heart [2].

The heart rate analysis method is based on its consideration as a process with a random nature, represented by the time series of cardio intervals (R-R intervals). In this analysis, various statistical processing systems are used. Cardio-cycles in a temporal aspect contain information on the activity of the cardiac system, as well as on higher-order regulatory mechanisms that control the functions of the whole organism at various levels. Thus, the use of heart rhythm as an integral parameter of the regulatory processes of the whole organism makes possible to evaluate the state of the adaptive capabilities of the animal's organism both on the somatic level of functioning of the autonomic nervous system and in the aspect of its adaptation [3].

However, investigations aimed at studying the question of the relationship of age-related changes in functional reserves with parameters of the economic characteristics of cows have not been described in literature. In this regard, the purpose of the study was to determine the age-related changes of economic parameters - milk production for 305 days and the intensity of milk production in Jersey cows with different stress index [4].

2 Materials and methods

Investigations of Jersey cows numbering 103 animals were carried out in livestock complex LLC Vakinskoe Agro in 2016 and 2018.

Clinical and electrocardiographic parameters were recorded for the studied animals.

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Clinical examination and a general study of the cardiovascular system were carried out according to the methods of clinical examination of animals by B.V. Usha. Clinical parameters included examination and determination of the general condition of the animal by hairline, skin and mucous membranes.

Evaluation of milk production and milk yield intensity of cows in 2016 (2nd lactation) and in 2018 (4th lactation) was carried out. During the study period, the animals were in the same conditions of feeding and housing in accordance with zoohygienic requirements.

To register the ECG, the integrated electrophysiological laboratory "CONAN – 4.5" was used in the frontal lead system according to the Roshchevskiy method 2-3 hours before meals. With the help of this laboratory, an additional cardiographic study was performed - an analysis of heart rate variability. The electrocardiogram was recorded for 3-5 minutes, while the cows under study were in a standing position.Statistical processing of the results was carried out with the help of program "Statistica 10" with the calculation of the following parameters: arithmetic average (M), arithmetic average error (m) and Student's t-test. Differences were considered significant at $p < 0.05$ [5].

3 Results and discussion

According to investigations. Jersey cows have stress indices. As a result of our research, an analysis of milk production in Jersey cows for three years was carried out.

Table 1 presents the comparative data of milk productivity (305 days) of Jersey cows in groups with different initial vegetative tonus of cows over several years

Table 1. Age-related changes in milk yield of cows with different IVT, M ± m

Stress index (SI), c.u.	IVT inSI	Milk yield for 305 days, kg			
		2016	2018	Remainder	%
lessthan 50	Vagotony	5448±162*	5080±120*	–368	6.75
51-150	Normotonia	5697±131*	5790±108*	+93	1.63
151-250	Sympathicotonia	5903±196*	5710±150*	–193	3.26
more than 251	Hypersympathicotonia	5668±189*	5300±123*	–368	6.75

Note: * is significant difference in milk production in 2016 and 2018 relative to the initial vegetative tonus (IVT) – $p< 0.05$

The analysis of Table 1 shows that initially the highest milk yield for 305 days - 5903 ± 196 kg is typical for cows with an IVT - sympathicotonia. Jersey cows of this group has certain functional reserves (energy, metabolic), and responds to the load that is provided by the lactation process mainly due to the autonomous contour of regulation.

However, during prolonged exercise, a certain tension of regulatory mechanisms is required to maintain homeostasis. This, apparently, leads to the mobilization of strategic reserves and the inclusion of central regulatory mechanisms and this, in turn, indicates a certain deficiency of innate functional reserves to maintain the lactation process for a long time [6].

Research data confirm this assumption. In 2018 milk yield in a case of sympathicotony was 5710 kg, a decrease of 3.26 % occurred and the remainder was 193 kg. In a case of hypersympathicotony, by 2018 there was a more significant decrease in milk yield by 6.75 % and the difference was 368 kg.

When hypersympathicotony, a central contour of regulation is involved, autonomic homeostasis is disturbed, and there is a lack of internal functional reserves. All this leads to a high degree of stress and reduced lactation function.

The lack of functional reserves is also characteristic of vagotony - the lowest milk yield is 5448 ± 162 kg. In 2018, the same group had a decrease in milk production by 368 kg.

Cows with normotony represented the only group in which milk yield in comparative characteristics increased over three years by 93 kg (1.63 %).

This can be explained by the fact that cows of this group have a certain reserve for normal lactation and maintaining high parameters for a long time. The heart of animals with higher energy and metabolic resources is capable of providing a higher minute volume of blood circulationat the same pulse rate.

At the same time, the same minute volume of the heart can provide greater delivery and utilization of oxygen with a lower stress of regulatory systems, i.e. is characterized by relatively higher information resources. It is obvious that the cardiovascular system of such cows will better ensure the functioning of certain body systems during lactation and, accordingly, is better prepared for the lactation process [7].

The relationship of milk yield of Jersey cows for 305 days for the period of 2016 and 2018 with the stress index is reflected in the dispersion pattern for several variables, presented in Figure 1.

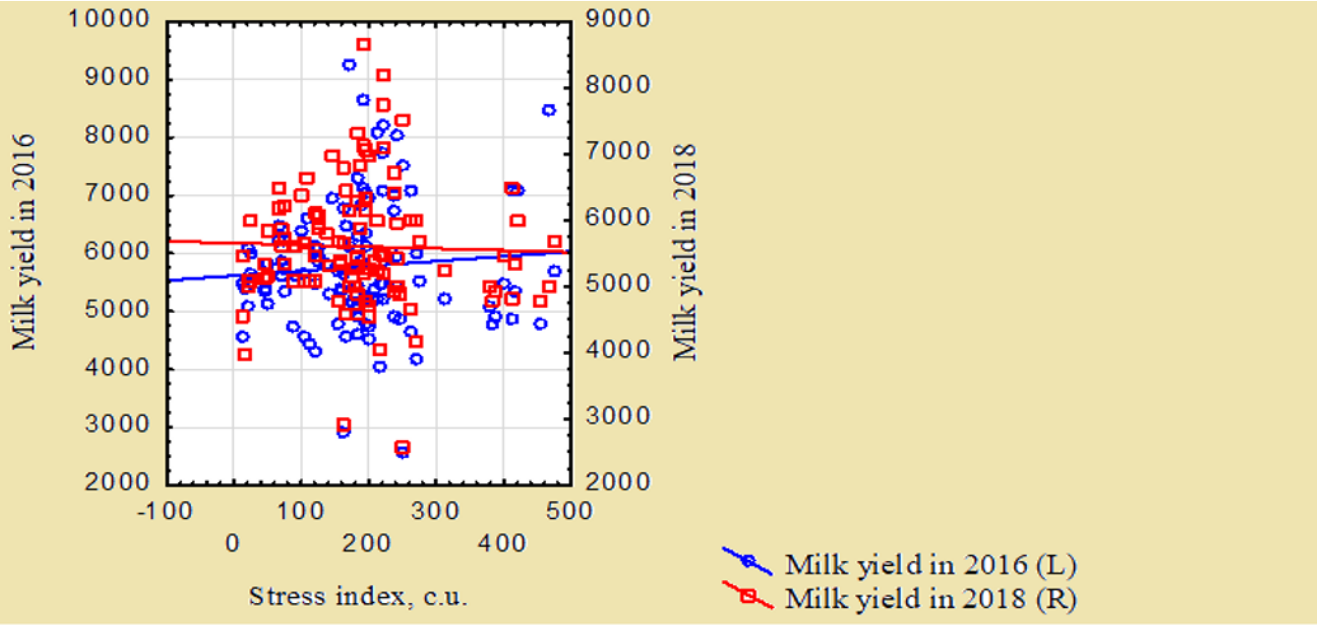

Fig. 1. The diagram of Jersey cows' milk yield dispersion for 305 days for the period of 2016 and 2018 with a stress index

When analyzing the diagram (Figure 1) for the period of 2016 and 2018 with the stress index, one can see that in 2016, the cows under study with increasing initial vegetative tonus (reflected with increasing stress index) gradually increase milk yield and the equation is y = 5619.05 + 0.83 x.

In 2018, animals with an increase in the initial vegetative tonus had some gradual decrease in milk yield for 305 days. The equation is y = 5658.72–0.27 x.

During the study, when examining electrocardiograms of Jersey cows, initial vegetative tones were established based on the stress index and to confirm the correct distribution of groups among the entire array, a classification matrix was constructed that reflects the true classification and even those that were not included in their groups.

Based on this matrix and the data obtained, the division into groups is performed correctly [8].

The variation in milk production of Jersey cows over 305 days for the period of 2016 and 2018 with a stress index is reflected in the linear graph for several variables in the dispersion diagram shown in Figure 2.

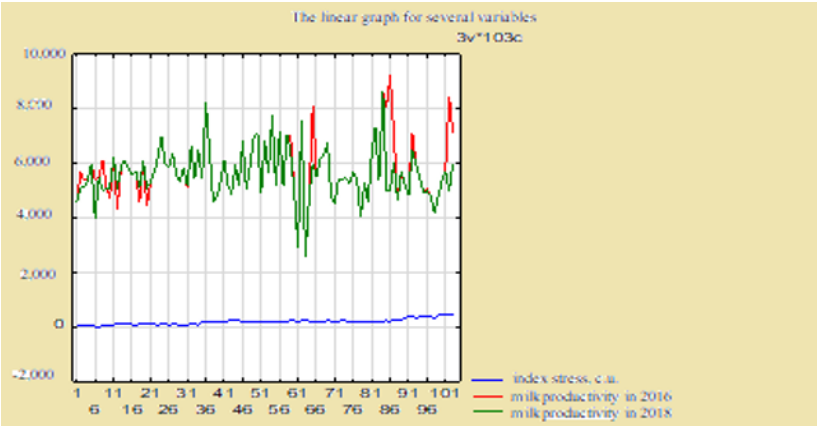

Fig. 2. Variation in milk productivity by years (2016 and 2018)

Figure 2 shows the changes in milk productivity of Jersey cows for 2016 and 2018 in relation to the stress index. The stress index gradually rises with a change in the initial autonomic tone, since there is a change in the work of controlling the central contours of the parasympathetic and sympathetic autonomic nervous systems. With age, some restructuring of the body occurs, that is, the processes of assimilation and dissimilation do not work as they did at a young age.

There are also changes in operation of the brain, namely in the posterior lobe of the pituitary gland, which is responsible for the release of oxytocin into the blood, which in turn is involved in the process of removing milk from the mammary gland. It becomes smaller with

age, and this is strongly associated with the autonomic nervous system [9].

So, with age, the sympathetic departments give their work to the parasympathetic nervous system. In this regard, the graph clearly shows the relationship between the work of these two subsystems of the autonomic nervous system, milk productivity prevailed among sympathicotonics (2016) and in normotonics (2018) and showed the highest productivity. The red lines on the graph show an increase in milk productivity in this study group. Thus, this group does not lose its functional reserves with age, but retains them in its information and metabolic processes in the body, since these systems are in balance.

Table 2 presents the data of the initial vegetative tonus of Jersey cows, as well as two columns of comparable data on the intensity of milk flow in 2016 and 2018.

When analyzing the table with the original data the following results are obtained. As can be seen from the table with an increase in the stress index, the intensity of milk flow increases accordingly.

Data analysis for 2016 for Jersey cows with different IVT calculated on the basis of SI shows the following results.

Table 2. Age-related changes in the intensity of milk flow in cows with different IVT, M ± m

SI, c.u.	**IVT inSI**	**Intensity of milk flow, kg / min**			
		2016	**2018**	**Remain der**	**%**
lessthan 50	Vagotony	1.7±0.2*	1.4±0.2*	-0.3	18
51-150	Normotonia	1.9±0.2*	1.9±0.2*	0	-
151-250	Sympathicotonia	2.2±0.3*	2.0±0.3*	- 0.2	9
more than 251	Hypersympathicotonia	2.8±0.7*	2.3±0.5*	- 0.5	18

Note: * is significant difference in intensity of milk flow in 2016 and 2018 relative to the initial vegetative tonus (IVT) – $p< 0.05$

In a case of vagotony, the stress index is less than 50 c.u., and the intensity of milk flow is 1.74 ± 0.28 kg / min. It is characterized by the lowest intensity of milk flow.

This is most likely due to the fact that the parasympathetic part of the autonomic nervous system prevails. This value is less by 0.23, 0.47 and 0.53 kg / min than in cases with normotony, sympathicotonia and hypersympathicotonia, respectively.

Innormotony, this parameter is more by 0.23 kg / min than invagotony and is 1.97 ± 0.29 kg / min, and less by 0.24 and 0.79 kg / min than insympathicotonia and hypersympathicotonia, respectively.

The value of this parameter insympathicotonia is 2.21 ± 0.31 kg / min, which is 0.47 and 0.24 kg / min more than invagotony and normotonia, respectively, but less by 0.55 kg / min than inhypersympathicotonia.

Jersey cows are characterized by the highest intensity of milk flow, which is 2.76 ± 0.76 kg / min. This value is more by 1.02, 0.79 and 0.55 kg / min, than invagotony, normotonia and sympathicotonia, respectively.

The analysis of the table shows that initially (in 2016) the milk flow rate increased with an increase in the stress index.

The highest one is observed in case ofhypersympathicotonia. Perhaps this is due to the fact that the action of the sympathetic nervous system on the heart is a little longer than the action of the vagus nerves, which is caused by the uneven rate of destruction of the mediators [10].

Presumably, the excretion of oxytocin in the blood during milking inhypersympathicotonia is higher than in other groups of cows.

Clearly, the dynamics of changes in the rate of milk flow over three years can be seen in the diagram (Figure 3). Cows with hypersympathicotonia and vagotony are subject to the most drastic fluctuations.

No sharp changes in the index were found in cows with an autonomous contour of regulation. 1.7

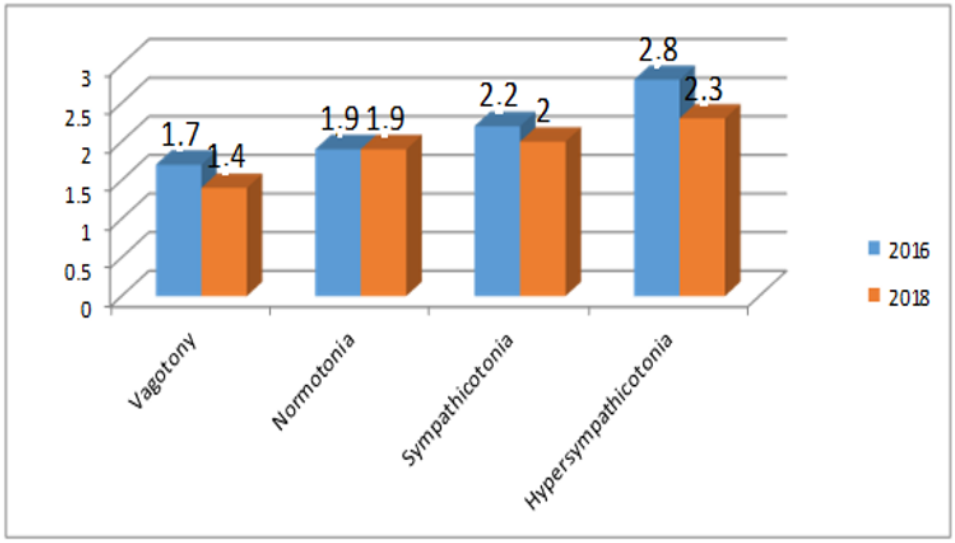

Fig. 3. The diagram of the intensity of milk flow of Jersey cows with different initial vegetative tone (2016 and 2018)

4 Conclusion

As a result of investigations, it was established that 305 days' milk yield of Jersey cows with different initial vegetative tone for 2016 and 2018 decreased in hypersympathicotonia and vagotony by 6.75 %, insympathicotonia by 3.26 % and increased innormotonia by 1.63 %. Analysis of the intensity of milk flow of Jersey cows with different initial autonomic tone for 2016 and 2018 showed that in cases of hypersympathicotonia and vagotony there was a decrease in the parameter by 18%, in a case of sympathicotonia by 9% and in case ofnormotonia the parameter did not change. Cows with normotonia are the most promising group in terms of the stability of economic characteristics in the process of animals' management. Their parameters do not decrease, but there is also a slight increase.

References

1. R.M. Baevskiy, Yu.S. Balashov, *Analysis of heart rate variability in health control system "Self-control"* in *Coll. of sc. works. For the first time in medicine* 15-16 (St. Petersburg, 1995)
2. I.V. Goncharenko, D.T. Vinnichuk, *Jersey breed of livestock in the US dairy industry* Advances in modern science **12**, 164-168 (2017)
3. A.S. Emelyanova, *The relationship of the functional state of the cardiovascular system and milk production of cows according to electrocardiographic examination* 139 (2010)
4. Yu.P. Borycheva, E.E. Stepura, S.D. Emelyanov, *Adaptive abilities of Jersey cows in modern conditions* in *Innovative development of the modern AIC of Russia. Mat. of the National Sci. and Pract. Conf.* 268-272 (2016)
5. A.P. Velmatov, A.M. Guryanov, O.N. Lukonina, et al. *Milk productivity and technological properties of cows of the red-motley breed of the Volga type* Agricultural Science of the Euro-North-East **5(36),** 47-50 (2013)
6. E.V. Verbovik, *Features of the autonomic regulation of cardiac activity in horses. Abstract of candidate dissertation* (Moscow, 2006)
7. D.S. Wilver, *Influence of the age of maternal ancestors on milk productivity and morphofunctional properties of the udder of black-motley cows* News of Orenburg State Agrarian University **2(52),** 138-140 (2015)
8. A.S. Danilenko, A.A. Elenshleger, *The methodology for evaluating the electrocardiogram in newborn calves being normal and with pathology* (Publishing house of ASAU, Barnaul, 2014)
9. L.S. Zhebrovskiy, V.E. Mitko, *Prediction of milk productivity of the cattle: a training manual* (Kolos, Leningrad, 1980)
10. S.N. Kopylov, *Heart rate variability in cows of different age* Veterinary medicine **2,** 49-50 (2012)