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The use of entropy and information analysis to estimate the milk productivity of the Black-and-White dairy breed cows depending on their lineal affiliation

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Abstract. In modern realities, an important place for the effective management of the cattle breeding industry is a properly implemented selection and breeding process with the sampling of cows that are marked by the highest indicators of a set of productive qualities. In this case, the application of entropy and information analysis is one of the most expedient, as it makes it possible to assess the economic and useful qualities of animals as fully as possible. The purpose of the study is to evaluate and analyze the degree of organization of the biological system of dairy cattle productive traits under the influence of hereditary factors such as the age and origin of cows. During the research, methods generally accepted in zootechnics and methods using information and entropy analysis, which are adapted and modified in animal husbandry, were used. The data obtained from the entropy and information analysis show that for cattle of the Black-and-White breed of different lineal affiliations, the level of organization of systems varies – R from 0.009 to 1.341 bits. Moreover, the most stable trait from the point of view of variability was the fat content in milk, the level of unconditional entropy in the section of lactations was equal to 3.333-4.550 bits, which indicates a smaller influence of disorganized factors on the level of manifestation of this trait, and a greater dependence on hereditary factors, i.e. origin. Although in general, a reliable influence of the lineal affiliation of cows on indicators of unconditional entropy and organization of the system was not established, the influence of the age factor on indicators of entropy was observed. Thus, the researched livestock is not characterized by uniformity and consolidation in terms of the main selection characteristics, except for the fat content in milk, which indicates a wide range of variability and serves as a flexible material both for selection and breeding work and for increasing the level of milk productivity. Therefore, the use of empirical data of information theory can be a kind of marker when predicting hereditary traits of a particular productivity, since entropy and information analysis provides wider and deeper values of trait variability

Keywords: information theory; milk yield; fat content in milk; entropy; organization of the system; measure of chaos

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INTRODUCTION

Since the 2000s, the use of entropy and information analysis (EIA) has attracted more and more attention in various areas of scientific practice, many publications can be found in biology, physiology, medicine, and since 2018, modeling and analysis of selection processes using information theory have been widely used in animal husbandry (Machado *et al.*, 2020; Chanda *et al.*, 2020; Mueller *et al.*, 2021).

Modeling the processes of system development becomes possible precisely due to the study of the mechanism of information transmission, which in turn, taking into account the degree of organization, orderliness and complexity, explains the essence of the mechanism of system progress (de Andrade *et al.*, 2022; Fuentes *et al.*, 2022).

The method of entropy analysis allows to increase the level of research of various indicators of economic and useful traits. When analyzing the dependencies between the entropy of nominal features and its expressiveness, the mutual information of natural descriptive statistics corresponds to the laws of information theory (Karatieieva *et al.*, 2021).

Entropy, as a logarithmic measure of disorder, characterizes the average degree of uncertainty of the state of the message source. The degree of uncertainty in information systems decreases due to the received information, therefore, in numerical terms, entropy is equal to the amount of information, that is, it acts as a quantitative measure of information. Entropy also has the feature of additivity, since the total entropy of several objects is equal to the sum of the entropy phenomena of individual objects (Pidpala *et al.*, 2018).

In agriculture, mathematical modeling methods are actively used to solve the following tasks: drawing up optimal animal feeding rations, determining the sexually mature structure of the herd, drawing up optimal timing of animal vaccination, drawing up lactation curves of milk yield, etc. However, for cattle breeding, they have a slightly different character, this is due to the fact that one of the most important components for these animals is the comprehensive assessment of cattle, for their further use in the selection and breeding process, and one of the advanced methods is precisely the method of mathematical modeling (Kramarenko *et al.* 2019).

The use of the method of entropy analysis makes it possible to identify natural and ecological consequences that significantly affect selection and production characteristics, as well as to choose the most compatible pairs for breeding, from the point of view of selection, and to eliminate from the selection process unsatisfactory animals that do not meet the requirements (Fuentes *et al.*, 2022). Therefore, the purpose of the research was to use information theory as an additional model for evaluating milk productivity of cows, determining the organization of the system as an indicator of the selection potential of a given herd.

LITERATURE REVIEW

The first works on information theory began to appear in mathematics and computer science. Thus, the American mathematician C. Shannon (1948) is the founder of the mathematical theory of information, and in his research, he used the concept of entropy in creating "codes resistant to interference" and in establishing the critical speed in information transmission. This approach, using statistical thermodynamics and the probabilistic function of entropy, turned out to be appropriate in the biological sciences as well (de Andrade *et al.*, 2022).

The concept of entropy for understanding biological systems was first applied by E. Schrödinger (1944a), using life phenomena, individual biological processes, and even human activities. Later, M. Delbrück (1962) continued his research, taking as a basis the nature of intermolecular forces observed in biological processes. T.P. Knowles *et al.* (2007) using entropy analysis elucidated the molecular origin of fibril material properties and showed that the main contribution to their stiffness comes from the general system of hydrogen bonds between backbones, which is modulated by various interactions of side chains.

Therefore, the probabilistic function of entropy allows to study all stages of the transition of a biological system from maximum disorganization, that is, a state of complete chaos, which is characterized by an equal value of probabilities and the maximum possible value of entropy itself, to a state of maximum permissible order of the system, in which the only possible state of segments of biological system would be observed (Landete-Castillejos & Gallego, 2000; Gray, 2011).

Many scientists consider a living organism, from the point of view of entropy, as a complex open system in which physical and chemical processes take place, which is in a disorganized, non-stationary state (Gray, 2011; Pidpala *et al.*, 2018; Kramarenko *et al.*, 2019). Therefore, the modeling process in biology is unique in its characteristics and at the same time quite complex, it is inextricably linked with such elements as: hypothesis, abstraction, analogy and others. This method is considered as a process of building, studying and applying mathematical models. If such an analysis is not carried out, there will be a significant decrease in indicators of animal husbandry development (Lemay *et al.*, 2009; Mueller *et al.*, 2021).

Since all exchange processes are balanced in living organisms, this causes a decrease in entropy and contributes to the maximum organization of the entire biological system. Therefore, thanks to entropy analysis, it is possible to provide a characteristic of the vital activity of a biological system or its element, which is not limited to a simple set of chemical and physical, microbiological, physiological processes, but is characterized by a number of other complex processes of self-regulation, which are given in the studies of various scientists (Erill, 2012; Ritchie & Van Steen, 2018; Fuentes *et al.*, 2022).

P.T. Krishnan *et al.* (2020) using entropy and information analysis established several correlations between differentially expressed genes and mental disorders. The authors used the Cell Signaling Network entropy approach, which consisted of the probability of gene interaction using matrix RNA (ribonucleic acid) quantification, calculating signal propagation within the network. The obtained data demonstrated a change in gene expression in disorders. However, the entropy of the cellular signaling network in each pathology showed no differences compared to the corresponding control values. In comparison, progenitor cells, stem cells, and tumor cells showed high entropy, meaning less information in cell signaling. Thus, the author concluded that the disturbance changes cell signaling in peripheral tissues, but supports cell differentiation and the amount of information (Krishnan *et al.*, 2020).

Similar studies were conducted by M.M. Breve *et al.* (2022) based on maximum entropy and using features extracted from graphs to classify mRNA and ncRNA sequences. The results showed the adequacy of the proposed methodology, achieving higher accuracy than in studies using variational statistics. In addition, the proposed method performed classification with less processing time, which indicates a reduction in complexity while maintaining confidence in classification.

The entropy-based method is more powerful than conventional methods and may be useful for detecting epistasis of rare genes, including in animal breeding (Schrödinger, 1944b; Nezhlukchenko, 1999; Pidpala *et al.*, 2018). Chinese scientists S. Liu *et al.* (2023) used a combination of hyperspectral imaging and the entropy method to comprehensively assess the activity of antioxidant enzymes in Tano lamb. The conducted studies indicate that entropy analysis may have great potential for future studies of various enzymes in meat.

Thus, the application of the technique of entropy analysis and information theory in breeding work with dairy cattle will provide more in-depth knowledge and form an understanding of the biological system from the point of view of variability according to the assessment indicators, based on the criteria of physiological factors, genetic factors and environmental factors that affect this biological system.

MATERIALS AND METHODS

The research was carried out on the basis of the agricultural production cooperative "Agrofirma "Myh-Servis-Ahro" of the Mykolaiv region, Ukraine, in the period 2019-2021. For the research in the experiment, an entropy and information analysis of the milk productivity of cows of the Black-and-White dairy breed was used depending on their lineal properties that come from three breeder bulls – Champion, Dragoon and Goliath.

At the first stage of research, for the perfect characterization of milk productivity of animals, biometric processing of the source information was carried out using the methods of variational statistics, and the method of N.A. Plokhinsky (1964) was used. Next, an entropy and informational analysis of the traits of milk productivity was carried out (in terms of 305 days of the first, second, third and higher lactations of cows using the method of K. Shannon (1983) in a modified version of O.S. Kramarenko *et al.* (2019). Based on the recommendations of Yu.G. Antamonov (1977) a classification of biological systems was carried out.

The intra-population value of the unconditional entropy of quantitative traits was determined using the formula:

$$H = -\sum_{i-1}^{k} (p_i \cdot log_2 \cdot p_i), \quad (1)$$

where H – the entropy of a specific statistical system; p_i – the probability (or frequency) of the variation of the characteristic according to the gradations of the variation series; k is the number of possible variants of the system (trait).

For this stage of the system at the maximum possible level, the theoretically determined entropy was calculated according to the formula:

$$H_{max} = log_2 \cdot k, \quad (2)$$

where H_{max} – maximum system uncertainty or degree of complexity; k – the maximum number of positions of the system of trait.

The level of absolute organization of the system was determined by the formula:

$$O = H_{max} - H. \quad (3)$$

The relative organization of the system and its level was calculated according to the formula:

$$R = 1 - H \div H. \quad (4)$$

It is when the entropy level is zero that the system has the highest level of organization. In deterministic systems, the value of relative entropy reaches its maximum and is up to 1. The indicator $R = 0$ occurs in completely disorganized systems.

In the study, the authors used the ARRIVE (n.d.) guidelines as a checklist and followed all relevant ethical norms.

RESULTS AND DISCUSSION

The use of diversity scores has a long history in population ecology, while population genetics has instead been dominated by measures based on variance, a technical gap that slows the breeding progress of a herd or breed. Using entropy in selection work, in contrast to variance, first a model of continuous chaotic diversity is constructed. And then a multiple nested division of diversity of alleles, individuals, populations, and species is created, each component of which engages in behavior of the corresponding diversity metrics, and then these components are converted into a scaled form of the system organization (Shannon, 1948). At the same time, non-parametric statistical tests of components within a population, breed or herd, and new tests of homogeneity of components of diversity within a population at any hierarchical level are also used (Schrödinger, 1944a; Narinc *et al.*, 2013; Liu *et al.* 2023).

The calculations that were performed determined that the limits of relative organization of the biosystem for the cows of the Champion line (Table 1) for the first three and higher lactations were $R = 0.027 – 0.679$. The age of cows was not a significant driving force in the change in the level of milk productivity in the conducted research, so this value was rather fluctuating. Significant indicators of unconditional entropy – $H = 3.612$ bits were observed during the first lactation. The level of unconditional entropy during the second lactation decreased its meaning to 1.688 bits, but it rose again during the third lactation – to 3.429 bits, it also showed a downward trend during the higher lactation – $H = 1.067$ bits, which indicates the level of entropy reduction, and accordingly the system becomes more ordered.

Examining the fat content in milk, the situation was characterized by significant stability, so the level of unconditional entropy in the first lactation was equal to $H = 4.222$ bits, during the second one it decreased slightly – 3.333 bits, the data from the third to higher lactations were identical – $H = 4.550$ bits. The amount of milk fat, which was also subject to research, did not show a significant manifestation of unconditional entropy and its positive correlation with the age of animals.

If analyzing the level of relative disorganization of the system (R), it should be noted that according to the classification of Yu. Antamonov (1977), this biological system was neither stable in terms of age nor productivity, and in most cases belonged to a stochastic ($R = 0.003 – 0.088$ bits) or quasi-deterministic (R=0.158-0.271 bits) system, only complete disorganization system was noted for milk yield at the age of the second and higher lactations ($R = 0.492 – 0.679$ bits). At that time, anentropy, regardless of age and productivity characteristics, acquired negative values, which reflects a higher degree of differentiation and heterogeneity of this biological system ($A = – 3.740 – 4.080$ bits).

Table 1. *EIA of milk productivity of the Black-and-White dairy breed of the Champion line*

Trait	n	Parameters of entropy and information analysis of a trait				
		$H \pm SE_H$	H_{max}	O	R	A
first lactation						
Milk yield for 305 days, kg	20	3.615 ± 0.452	3.322	0.293	0.088	-3.939
Fat content in milk, %	20	4.222 ± 0.444	3.322	0.900	0.271	-3.935
Amount of milk fat, kg	20	3.846 ± 0.512	3.322	0.524	0.158	-3.980
second lactation						
Milk yield for 305 days, kg	20	1.688 ± 0.048	3.322	1.634	0.492	-3.780
Fat content in milk, %	20	3.333 ± 0.319	3.322	0.011	0.003	-3.897
Amount of milk fat, kg	20	2.063 ± 0.095	3.322	1.259	0.379	-3.839
third lactation						
Milk yield for 305 days, kg	20	3.429 ± 0.371	3.322	0.107	0.032	-3.939
Fat content in milk, %	20	4.550 ± 0.487	3.322	1.228	0.370	-3.747
Amount of milk fat, kg	20	3.231 ± 0.347	3.322	0.091	0.027	-3.797
higher lactation						
Milk yield for 305 days, kg	20	1.067 ± 0.002	3.322	2.255	0.679	-3.780
Fat content in milk, %	20	4.550 ± 0.487	3.322	1.228	0.370	-3.747
Amount of milk fat, kg	20	3.563 ± 0.358	3.322	0.241	0.072	-4.080

Notes: *n is the number of animals to be studied*
Source: *author's development*

Conducting an entropy and information analysis for cows of the Dragoon line (Table 2), it should be noted that the maximum possible entropy indicator reached H_{max} = 3.322 bits. And the maximum value of unconditional entropy was obtained by milk yield during the third lactation – with a value of *H* = 3.133 bits.

Table 2. *EIA of milk productivity of the Black-and-White dairy breed of the Dragoon line*

Trait	*n*	Parameters of entropy and information analysis of a trait				
		$H \pm SE_H$	H_{max}	*O*	*R*	*A*
first lactation						
Milk yield for 305 days, kg	20	2.000 ± 0.101	3.322	1.322	0.398	-3.839
Fat content in milk, %	20	2.647 ± 0.174	3.322	0.675	0.203	-3.971
Amount of milk fat, kg	20	1.000 ± 0.008	3.322	2.322	0.699	-3.622
second lactation						
Milk yield for 305 days, kg	20	3.059 ± 0.234	3.322	0.263	0.079	-3.997
Fat content in milk, %	20	3.813 ± 0.413	3.322	0.491	0.148	-4.030
Amount of milk fat, kg	20	2.067 ± 0.097	3.322	1.255	0.378	-3.822
third lactation						
Milk yield for 305 days, kg	20	3.133 ± 0.280	3.322	0.189	0.057	-3.922
Fat content in milk, %	20	1.133 ± 0.012	3.322	4.455	1.341	-3.522
Amount of milk fat, kg	20	2.000 ± 0.079	3.322	1.322	0.398	-3.839
higher lactation						
Milk yield for 305 days, kg	20	2.563 ± 0.168	3.322	0.759	0.229	-3.813
Fat content in milk, %	20	2.286 ± 0.138	3.322	1.036	0.312	-3.780
Amount of milk fat, kg	20	2.813 ± 0.205	3.322	0.509	0.153	3.839

Notes: *n is the number of animals to be studied*
Source: *author's development*

Comparing the indicators of the first and second lactations in more detail, it can be seen that the entropy level decreased from *H* = 3.059 to *H* = 2.000 bits. The level of relative and absolute organization of the trait according to milk yield showed a clear dominance for the first lactation, for which their values were – *O* = 1.322; *R* = 0.398 respectively. At the same time, the level of unconditional entropy for higher lactation reached a value of *H* = 2.563 bits. Cows of the Dragoon line were characterized by milk yield as complex-stochastic systems (*R* = 0.0179 – 0.148 bits), but in the second and higher lactations they were simple-quasi-deterministic systems (*R* = 0.229 – 0.398 bits).

According to the content of fat in milk, the level of organization of the system compared to the value of milk yield had higher indicators and reached for the second and third lactation – *O* = 0.491 and *O* = 4.455 bits, respectively. And this, in turn, automatically reduced the level of unconditional entropy from *H* = 3.813 bits to *H* = 1.133 bits.

When studying the amount of milk fat, a tendency to increase the value of unconditional entropy was noted. So, for the first lactation, its indicator was *H* = 1.000 bits, and for the higher one, *H* = 2.813 bits. This contributed to the decrease with age of the index of conditional organization of the system – from *O* = 2.322 bits for the first lactation to *O* = 0.509 bits for higher lactation. Accordingly, there was a decrease in the indicator of the relative organization of the system. Thus, the level of relative entropy for the first lactation was *R* = 0.699 bits, which characterized this herd as a disorganized system. At the same time, with age, there was a tendency to decrease this parameter: *R* = 0.378 bits for the second lactation and *R* = 0.153 bits for higher lactation. This contributed to the gradual orderliness of the system and transferred the animals from a chaotic completely disorganized system, first to a quasi-deterministic system (*R* = 0.378 bits) – the second lactation, and then to a deterministic ordered system (*R* = 0.153 bits) – higher lactation.

Anentropy indicators from *A* = –3.522 bits to *A* = –4.030 bits were noted within the permissible values, regardless of the age of the animals and the selection trait, its negative values were observed. A similar trend is observed in the characteristics of the entropy of the breeding and productive traits of cows of the Goliath line (Table 3).

Table 3. *EIA of milk productivity of the Black-and-White dairy breed of the Goliath line*

Trait	*n*	Parameters of entropy and information analysis of a trait				
		$H \pm SE_H$	H_{max}	*O*	*R*	*A*
first lactation						
Milk yield for 305 days, kg	20	3.125 ± 0.256	3.322	0.197	0.059	-3.913
Fat content in milk, %	20	3.500 ± 0.298	3.322	0.178	0.054	-3.954
Amount of milk fat, kg	20	3.438 ± 0.322	3.322	0.116	0.035	-3.939
second lactation						
Milk yield for 305 days, kg	20	1.867 ± 0.072	3.322	1.455	0.438	-3.780
Fat content in milk, %	20	3.941 ± 0.410	3.322	0.619	0,186	-4.013
Amount of milk fat, kg	20	2.867 ± 0.221	3.322	0.455	0.137	-3.822
third lactation						
Milk yield for 305 days, kg	20	3.250 ± 0.279	3.322	0.072	0.022	-3.880
Fat content in milk, %	20	3.625 ± 0.355	3.322	0.303	0.091	-3.803
Amount of milk fat, kg	20	2.267 ± 0.118	3.322	1.055	0.318	-3.780
higher lactation						
Milk yield for 305 days, kg	20	3.000 ± 0.236	3.322	0.322	0.097	-3.813
Fat content in milk, %	20	1.667 ± 0.055	3.322	1.655	0.498	-3.739
Amount of milk fat, kg	20	3.353 ± 0.285	3.322	0.031	0.009	-3.913

Notes: *n is the number of animals to be studied*
Source: *author's development*

Characterization of cows' milk yield connected with lactations determined a wave-like fluctuation of entropy with the age of cows. Thus, a significant decrease in the level of entropy by milk yield was observed at the age of the first and second lactations, and its level was *H* = 3.125 bits and *H* = 1.867 bits, respectively. During the third lactation, an increase in the value to 3.250 bits was noted, and during the higher lactation, its level decreased again to *H* = 3.000 bits.

The value of the absolute organization of the system was also characterized by relativity, as well as the indicator of the previous feature manifestation had a wave-like tendency. Namely, during the first lactation, the absolute organization of the system was *O* = 0.197 bits, at the age of the second lactation, its value increased to 1.455 bits and decreased again to *O* = 0.072 bits in the third lactation, and at the age of higher lactation, it reached its maximum value – *O* = 0.322 bits. At the same time, its relative organization had other indicators and had a tendency to gradually decrease *R* = 0.059 – 0.022 bits, excluding the second lactation – *R* = 0.438 bits. It characterized the investigated objects in the first case as a stochastic deterministic system, and in the second case as a completely disorganized one.

According to the level of unconditional entropy, the fat content in milk from the first to the third lactation was relatively stable – *H* = 3.500 – 3.941 0 3.625 bits, respectively, and it decreased radically only at the age of higher lactation – *H* = 1.667 bits. It should be noted that according to the fat content in the milk the Goliath line cows were simple stochastic *R* = 0.054 – 0.186 bits, excluding higher lactation – R = 0.498 bits, where the studied cows turned into a chaotic system, which may be due to the fact that higher lactation is a fairly subjective indicator, since it includes cows of different ages. High determination of the feature is inherent in cows in all age periods – respectively *O* = 0.178; *O* = 0.619; *O* = 0.303; *O* = 1.655 bits. Also, it should be noted that the entropy of polygenes, which are responsible for the implementation of the milk fat feature, decreases with the age of cows.

Among the studied animals of this group, the indicator of the amount of milk fat was marked by a fairly stable level of unconditional entropy *H* = 2.267 – 3.438 bits. In general, according to the amount of milk fat, cows of the Goliath line at the age of the first and higher lactations were found to be complex stochastic systems, but at the age of the second lactation they were simple quasi-deterministic systems (*R* = 0.035 bit; *R* = 0.009 bit and *R* = 0.137 bit). This confirms the opinion that cows with age can sustainably and for rather a long period of time maintain a high productivity potential.

Similar works were also carried out by a number of scientists R. Fan *et al.* (2011), F.V. Lishout *et al.* (2013), M.D. Ritchie & K.V. Steen (2018), who used empirical data using entropy analysis to identify interactions between genes and the features they cause. The correlation between indicators of milk productivity and genes associated with it was studied by H. Dehghanzadeh *et al.* (2020). As a result of research of metabolic pathways of genes based on gene annotations, it was found that the proposed clustering method gives correct, logical and fast results.

A. Borowska *et al.* (2018) used information theory as an alternative statistical approach to identify sections of the genome and candidate genes associated with economically useful livestock traits. The results of the study showed that important sections of the genome and candidate genes that determine variable qualities of bull sperm are located on several chromosomes. The scientists proved the validity of the influence of Single Nucleotide Polymorphism (SNP) on some variable quality of Holstein-Friesian bulls by means of entropy analysis.

Basing on entropy, scientists O. Fukuda *et al.* (2013) built a Radial basis function (RBF) neural network model to predict the live weight of pigs based on the growth parameters of Landrace sows. The results showed that the modeling method based on the RBF neural network using entropy analysis was an effective way to build a pig live weight prediction model. Entropy eliminated the collinearity of the independent variables in the linear regression analysis and predicted pig live weight better than the linear regression model.

E. Karatieieva *et al.* (2021) confirmed that animals with a high level of order of systems by live weight will, accordingly, have a high level of order of systems represented by the main indicators of milk productivity. The expediency of using information theory is also confirmed by M.S. Kwon *et al.* (2014), they prove that the use of entropy analysis of gene interaction (GGI) can reveal a large part of the obscure heritability of complex traits.

Thus, the obtained results make it possible to state that the use of information theory in breeding work with animals can be used as an additional indicator of their evaluation according to the main economically useful characteristics, in particular, their milk productivity. It will allow to get a more accurate and complete assessment and to predict their future milk productivity even in the early stages of development.

CONCLUSIONS

Processes influencing the degree of determinism of the system of productive qualities of cows of different lineal affiliations depending on their age were studied. It was established that the actual degree of values of unconditional and conditional entropy shows the result of combinative variability between polygenes and the traits they control, and the change of the traits themselves in the process of ontogenesis is the effect of gene expression and their interaction with environmental factors. Thus, the calculations of entropy and information analysis demonstrate that Black-and-White cattle, in relation to the importance of the organization of biological systems, which were represented by the main traits of milk productivity, do not have an unambiguous level of manifestation of their organization. Wave-like dynamics of the level of unconditional entropy were observed for the studied cows, that is, it sometimes decreased, then increased, depending on certain characteristics, such as milk yield and the amount of milk fat. At the time when the fat content in milk showed a gradual decrease in the level of unconditional entropy, which can be caused by selection and breeding work and the effect of stabilizing selection in the herd. At the same time, no dependence was found between the origin of the cows and indicators of their orderliness or disorganization. That is, the entropy analysis did not confirm the influence of the hereditary factor – the origin of cows on the level of their organization of the system. At the same time, the studied animals, according to the main characteristics of selection, both in terms of age and in terms of lineal affiliation, are not of the same type and uniform. According to the degree of organization of the system, they belong to different classification groups: stochastic, quasi-deterministic, deterministic, simple and complex, this indicates a high degree of variability in this herd. This, in turn, is a good indicator, as the studied herd has a high potential and reserve, both for increasing the level of milk productivity and for further breeding work with this herd. Entropy and information analysis will be used for the comprehensive assessment of this herd in the future in order to investigate the influence of paratypic reproductive qualities, such as the age of first insemination and calving season on indicators of milk productivity. They are essential factors in the formation of breeding traits and they have a probable influence on the level of productive qualities.

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CONFLICT OF INTEREST

None.

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Використання ентропійно-інформаційного аналізу для оцінки молочної продуктивності корів чорно-рябої молочної породи в залежності від їх лінійної приналежності

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Анотація. В сучасних реаліях важливе місце для ефективного ведення галузі скотарства є вірно здійснений селекційно-племінний процес з відбором корів, які відмічаються найвищими показниками сукупності продуктивних якостей. В даному випадку застосування ентропійно-інформаційного аналізу є одним із найбільш доцільних, оскільки дає можливість оцінити господарсько-корисні якості тварин максимально повно. Мета дослідження полягає в оцінці та аналізу міри організованості біологічної системи продуктивних ознак молочної худоби під впливом спадкових факторів таких як вік та походження корів. В ході дослідження використовувалися загальноприйняті в зоотехнії методики та методи з використанням інформаційно-ентропійного аналізу, які адаптовані та модифіковані у тваринництві. Одержані дані з проведення ентропійно-інформаційного аналізу демонструють, що для великої рогатої худоби чорно-рябої породи різної лінійної належності рівень організованості систем коливається – R від 0,009 до 1,341 біт. При чому, найбільш стабільною ознакою з точки зору мінливості виявився вміст жиру в молоці, рівень безумовної ентропії у розрізі лактацій дорівнював 3,333-4,550 біт, що вказує на менший вплив дезорганізованих факторів на рівень прояву даної ознаки, а більшу її залежність від спадкових чинників, тобто походження. Хоча в цілому достовірного впливу лінійної належності корів на показники безумовної ентропії та організованості системи не встановлено, але спостерігався вплив вікового фактору на показники ентропії. Таким чином, досліджуване поголів'я за основними селекційними ознаками, за виключенням вмісту жиру в молоці, не характеризується одноманітністю та консолідованістю, що вказує на широкий діапазон мінливості і слугує пластичним матеріалом як для селекційно-племінної роботи так і для підвищення рівня молочної продуктивності. Тож, використання емпіричних даних теорії інформації може бути своєрідним маркером при прогнозуванні спадкових ознак тієї чи іншої продуктивності, оскільки, ентропійно-інформаційний аналіз надає більш ширші та глибші значення мінливості ознаки

Ключові слова: теорія інформації; надій; вміст жиру в молоці; ентропія; організованість системи; міра хаосу