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MODERN APPROACHES TO THE ASSESSMENT OF PRODUCTIVE QUALITIES OF SHEEP OF ASCANIA FINE-WOOL BREED

Olena Karatieieva[1], Vadim Posukhin[1]

[1] Mykolayiv National Agrarian University, 54020, 9 George Gongadze Str., Mykolaiv, Ukraine

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Abstract

The study reflects the results of the evaluation analysis of the productive qualities of sheep of the Askanian fine-wool breed using modern methods. One of the main points in the selection and breeding business is the selection of animals with the best indicators of valuable economically useful traits. In modern practice, the selection of animals is carried out according to a complex of valuable traits and qualities, since the selection of animals for only one trait is not of particular value to the breeder. Using a number of modern techniques, which is one of the most relevant in this case. Calculations of the entropy-information analysis of live weight and wool length showed that the young stock of the Askanian fine-wool breed, in terms of the level of organization of systems, was characterized by ambiguous data on the organization of the system and relative entropy, which indicates sufficient disorganization of the system and provides opportunities for selection, has the potential to increase productivity. At the same time, sexual demorphism in the manifestation of signs of entropy was revealed, so the ewes of all experimental groups tended to reduce the level of unconditional entpropy. And the use of genetic and mathematical modeling showed a clear advantage in live weight of ewes and rams, which were the descendants of the first sire No. 483, which can characterize him as a carrier of the best hereditary characteristics regarding the ability to transmit high productive traits to the next generations.

Keywords: wool productivity, Askanian fine-wool breed, economically useful traits, entropy-information analysis, genetic and mathematical models

INTRODUCTION

Selection and breeding work in sheep breeding is a system of zootechnical techniques, measures and methods aimed at assessing and accounting for the productivity of animals, analyzing the origin and pedigree with the aim of further predicting and evaluating sheep in terms of the quality of the offspring, which will make it possible to obtain animals that in each subsequent generation in their productive qualities will surpass their parents (Haile *et al.*, 2020; Land and Robinson, 2013; McRae *et al.*, 2014; Tomes *et al.*, 2013).

Modern assessment methods in selection and breeding work largely depend on the specific direction of scientific research and the work of the breeder in order to trace the heritability of certain traits in animals. What makes it possible to increase the productive qualities of sheep in the future (Ferguson *et al.*, 2017; Nezhlukchenko *et al.*, 2020; Van Der Werf *et al.*, 2017).

One of the main points in the selection and breeding business is the selection of animals with the best indicators of valuable economically useful traits. In modern practice, the selection of animals is carried out according to a complex of valuable traits and qualities, since the selection of animals for only one trait is not of particular value to the breeder. Using a number of modern techniques, which is one of the most relevant in this case (Marai and Owen, 2013; Chihirov *et al.*, 2020).

The method of entropy analysis makes it possible to increase the accuracy of studies of the influence of various factors on economically useful traits. When analyzing the dependencies between the entropy of nominal features and its function, mutual information acts as a proper descriptive statistic (Fan *et al.*, 2011; Karatieieva *et al.*, 2021).

The entropy-based method is more powerful than conventional methods and may be useful for detecting rare gene epistasis, also in sheep breeding (Kramarenko and Lugovoi, 2013; Nezhlukchenko, 1999).

In the analysis of entropy, the dependence of features is determined by mutual information. Simulation studies conducted by C. Shannon show the correctness and expediency of this approach (Shannon, 1948).

In agriculture, mathematical modeling methods are actively used to solve the following problems: compiling optimal animal feed rations, determining the sexually mature structure of the herd, compiling the optimal timing of animal vaccination, compiling lactation milk yield curves, and more. However, for sheep 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 assessment of sires by the quality of their offspring, for their further use in the selection and breeding process, and one of the advanced methods is precisely the method of mathematical modeling (Landete-Castillejos and Gallego, 2000; Narinc *et al.*, 2013).

The modeling process itself 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 constructing, studying and applying mathematical models. If such an analysis is not carried out, then there will be a significant decrease in the development of sheep breeding (Mueller *et al.*, 2021).

Numerous studies in the field of agriculture and sheep breeding show that the future of this industry directly depends on the active implementation and application of modern modeling methods, both genetic-mathematical and mathematical-statistical (Bastanchury-López *et al.*, 2019; Gizaw *et al.*, 2010; Hvostik, 2021; Kwon *et al.*, 2014; Ostapchuk *et al.*, 2022).

Thus, the most efficient assessment of sheep is possible using the mixed biometric model method. Which includes traditional assessment methods and more modern ones, such as genetic models and entropy analysis, which makes it possible to take into account the influence of genotypic and paratypical factors simultaneously. This approach makes it possible to identify the natural and ecological consequences that have a significant impact on the offspring of their parents, as well as to select the most compatible pairs for breeding, from the point of view of selection. This is what sparked our interest in this study.

MATERIALS AND METHODS

For the study, three groups of sheep were formed, which come from three different rams, which were compared with each other according to the main economic and useful traits. Further, within each group, the experimental sheep were divided into sex groups of rams and ewe lambs, which were compared with each other and their productive qualities were evaluated according to the methods generally accepted in zootechnics (Tab. I).

Entropy-information analysis of live weight and hair length at the age of 12 months, as well as average daily, absolute and relative gains was performed according to the method of S. Shannon (Shannon, 1983) modified by S. S. Kramarenko (Kramarenko, 2005). The classification of systems was carried out according to the proposals of Y. G. Antamonov (Antamonov, 1977).

For the purpose of genetic and mathematical modeling and construction of theoretical curves for the live weight of replacement young animals, two models were used: the B. Gompertz equation and the equation of Z. Guo and G. Svalve (Gompertz, 1825; Guo and Svalve, 1995).

Statistical data processing was carried out using the Microsoft Excel software package and Statistica 6.1 according to G. F. Lakin (Lakin, 1990; Plohinskij, 1964).

RESULTS AND DISCUSSION

Entropy-Information Analysis of the Main Features of the Selection of Young Stock of the Ascanian Fine-Wool Breed

The use of entropy-information analysis (EIA) is a fairly commonly used technique in various sciences. At the same time, most of these studies demonstrate examples of the application of EIA in relation to discrete (qualitative) features that have a polynomial distribution, for which the basic provisions of information theory and, in particular,

I: *Scheme of the formation of experimental groups*

Experimental Group					
I (Sheep № 483)		II (Sheep № 256)		III (Sheep № 628)	
ewe lambs	rams	ewe lambs	rams	ewe lambs	rams
16	5	16	5	16	5

II: *EIA parameters of the main economically useful traits of young sheep of the Askanian fine-wool breed*

Group		n	Parameter of entropy-information analysis				
			$H \pm SE_H$	H_{max}	O	R	A
Live weight, kg							
I (Sheep № 483)	ewe lambs		1.922 ± 0.155	3.322	1.400	0.421	-2.493
	rams		1.958 ± 0.163	3.322	1.310	0.126	-2.256
II (Sheep № 256)	ewe lambs		1.522 ± 0.126	3.322	1.800	0.542	-2.825
	rams		1.426 ± 0.155	3.322	1.540	0.426	-2.523
III (Sheep № 628)	ewe lambs		1.922 ± 0.155	3.322	1.400	0.421	-2.493
	rams		1.578 ± 0.144	3.322	1.235	0.318	-1.423
Wool length, cm							
I (Sheep № 483)	ewe lambs		1.000 ± 0.000	3.322	2.322	0.699	-3.122
	rams		1.585 ± 0.000	3.322	1.737	0.523	-2.846
II (Sheep № 256)	ewe lambs		1.234 ± 0.121	3.322	1.358	0.623	-2.318
	rams		1.371 ± 0.246	3.322	1.951	0.587	-2.784
III (Sheep № 628)	ewe lambs		1.052 ± 0.003	3.322	1.172	0.124	-1.102
	rams		1.356 ± 0.010	3.322	1.254	0.322	-1.495

EIA were developed as the initial ones (Kramarenko and Lugovoi, 2013; Ritchie and Van Steen, 2018).

It is this method that makes it possible to study the main mechanisms of information transfer, and as a result, to plan the modeling of the system development processes in a certain direction. In turn, this makes it possible to increase the degree of organization, to clarify the mechanisms for the progress of the system, taking into account its orderliness or complication (Karatieieva *et al.*, 2021; Shannon, 1948).

The results obtained by different authors indicate the promise of using this method for the analysis of quantitative traits, which aroused our interest in the direction of these studies (Fan *et al.*, 2011; Kramarenko, 2005; Kwon *et al.*, 2014; Pidpala *et al.*, 2018).

Entropy-information analysis of live weight found that the formed groups of young animals of the Askanian breed, regardless of sexual demorphism, were stochastic systems, and the maximum entropy of all groups and indicators was 3.322 bits (Tab. II).

The level of unconditional entropy reached the level of 1.426–1.958 bits and found a clear downward trend in this indication among the representatives of the second group - 1.426–1.522 bits, which indicates a high consolidation of this trait among the representatives that were obtained from ram No. 256. The limits of the relative organization of the biosystem in terms of live weight were 0.126–0.542 bits, which indicates a sufficient organization of the biological system. By the level of organization of the system, no unambiguous trend was established, and its level ranged from O = 1.235 bits to O = 1.800 bits, which indicates a wide range of variability and potential for selection during selection.

The entropy-information analysis of the length of the wool found that the value of the unconditional entropy compared to the live weight tended to decrease from 1,000 bits to 1,585 bits, which indicates the uniformity of the herd for this trait. At the same time, there was no clear advantage of one or another group in terms of the level of unconditional entropy, but its dependence on gender was noted. That is, the ewes of all experimental groups tended to decrease the level of unconditional entpropy along the length of the wool, which indicates the consolidation of the herd in this indicator.

The use of entropy is widely used in various branches of animal husbandry. So, E. Karatieieva, I. Galushko, E. Kravchenko, M. Gill, found that animals with a high level of system ordering by live weight, respectively, will have a high degree of system ordering, represented by the main indicators of milk production (Karatieieva *et al.*, 2021). At the same time, M. S. Kwon, M. Park & T. Park confirm that the use of gene interaction entropy analysis (EIA) can unravel much of the unexplained heritability of complex traits (Kwon *et al.*, 2014).

Thus, the use of EIA can serve as a kind of marker in predicting the hereditary traits of a particular productivity.

Genetic-Mathematical Modeling of the Live Weight of Young Askanian Fine-Wool Breeds

Recently, it has become common in animal husbandry to use the technique of genetic-mathematical assessment and modeling of the dynamic processes of the body using various equations (Orikhivskyi *et al.*, 2019; Otwinowska-Mindur *et al.*, 2016; Satoshi Yamaguchi *et al.*, 2007; Tjørve and Tjørve, 2017). This is due to the possibility of early assessment of the genotype in order to early predict future performance and accelerate generational change.

Curves can be classified according to the type of growth: deterministic or indefinite. Most of the curves currently in use describe deterministic growth because this is easily observed in animals such as sheep and cattle. These curves are also referred to as asymptotic curves because such growth is determined by the maximum size achieved when the growth rate decreases (Brody *et al.*, 1923; Prasad and Singh, 2001). Recently, non-linear mixed-effects models have emerged that have become very popular in the analysis of growth data, as these models allow quantification of the mean as well as population variability in structural parameters. The model's non-linear mixed effect provides a powerful extension of the traditional regression model for organism growth data. These models include both fixed effects and random effects (Hvostik, 2021; Landete-Castillejos and Gallego, 2000).

Therefore, we set a goal to analyze the live weight of young sheep depending on their origin and apply the asymmetric functions of Z. Guo and G. Svolva and B. Gompertz, which allow us to evaluate the effects of hereditary components on the body - the growth rate of the body, the live weight of the sheep at the beginning of the period while taking into account environmental factors.

According to the results of the genetic and mathematical modeling of the live weight of young sheep of the Askanian fine-wool breed, we found that the B. Gompertz model is much more correct and reliable characterizes the change in the level of live weight during the entire growing period. She most accurately described the mass of ewes and rams at the age of six months - the deviation of the theoretical from the actual live weight was ♀ 0.34%, ♂ 0.23, twelve months old - ♀ 1.28%, ♂ 1.30% and 15 months old was ♀ 1.78% ♂ 1.71% (Tab. III). At the same time, the greatest differences in actual live weight from the theoretical one were noted at birth ♀ 4.42%, ♂6.68% and at the age of eight months - ♀ 5.64% ♂ 6.11%, respectively.

The study of descriptive modeling of the live weight of rams and ewes showed a similar direction of deviation of the theoretical live weight from the actual one in relation to different age periods. That is, the highest determination of deviations was observed at birth and at the age of 4 and 8 months - 4.42%.

III: *Parameters of B. Gompertz model for live weight of young animals Sheep of the Askanian fine-wool breed*

Age	Parameters of B. Gompertz model					
	Ewe lambs			rams		
	actual	theoretical	actual	theoretical	actual	theoretical
I (Sheep № 483)						
at birth	4.0	8.42	-4.42	5.06	11.74	-6.68
4	27.4	22.03	5.37	38.4	30.81	7.58
6	36.1	35.6	0.34	52.6	52.37	0.23
8	40.0	45.6	-5.64	64.0	70.01	-6.11
12	52.9	51.6	1.28	83.6	82.30	1.30
15	56.7	54.9	1.78	91.6	89.88	1.71
II (Sheep № 256)						
at birth	4.0	8.34	-4.34	4.6	11.2	-6.59
4	26.4	21.3	5.09	36.7	29.5	7.25
6	35.3	34.5	0.76	51.1	50.5	0.61
8	39.0	44.3	-5.30	62.0	68.2	-6.19
12	50.7	50.4	0.35	82.1	80.6	1.44
15	56.0	53.8	2.20	90.1	88.6	1.53
III (Sheep№ 628)						
at birth	3.6	7.8	-4.19	4.4	10.8	-6.46
4	25.3	20.4	4.93	35.7	28.8	6.89
6	33.7	33.4	0.31	50.5	49.6	0.87
8	38.6	43.0	-4.45	61.0	67.1	-6.13
12	49.2	49.1	0.14	80.6	79.4	1.20
15	54.5	52.5	2.03	88.8	87.1	1.65

In the period of six, twelve, fifteen months, this model more correctly described the live weight, and its theoretical and actual discrepancies were at the level of ♀ 0.34–1.78% and ♂ 0.23–1.71%.

As for the consideration of the discrepancy between the actual live weight and the theoretical one for the other two groups studied, they are absolutely similar to the first one for each of the age periods and differed exclusively in numerical values.

Similar data were obtained by a number of domestic and foreign scientists (Hvostik, 2021; Karateeva and Polishchuk, 2018; Tjørve and Tjørve, 2017; Oliyar *et al.*, 2020).

The characterization of changes in the level of live weight, using the parameters of the model of Z. Guo and G. Svolva, allowed us to observe a certain analogy with the previously studied parameters of the B. Gompertz model. In both cases, every month there was a deviation of the actual from the theoretical live weight. The difference between them consisted in a certain shift in the level of probability and discrepancies in age periods with a change in their level (Tab. IV).

A more accurate description of the weight was observed at the age of 6 months, where the deviation of the theoretical from the actual live weight was ♀ - 0.09%, ♂ - 1.14% and in 15% of the months ♀ 0.53%, ♂ 0.19%, for each from the three study groups.

The age periods at birth, four and eight months, occupied an intermediate position, and were characterized by an average degree of deviation at the level of ♀ - 0.90%, ♂ - 1.07% at birth; ♀ - 2.80%, ♂ - 3.65% for 4 months and ♀ 2.01%, ♂ 2.84% for 8 months.

The greatest discrepancy between the level of actual live weight and the theoretical one was noted only at the age of eight months - ♀ - 4.35% and ♂ - 4.48%.

Drawing conclusions from the descriptive modeling of the live weight of rams and ewes, we observed a similar direction of differences between the theoretical live weight and the actual one, as in the case of the B. Gompertz model. However, for the model of Z. Guo and G. Svolva, the discrepancy during the entire study period was much less pronounced than in previous studies, and is significant only in the period of 8 months.

IV: *Model parameters of Z. Guo and G. Svolva in terms of live weight of young sheep of the Askanian fine-wool breed*

Age	Model parameters of Z. Guo and G. Svolva					
	ewe lambs			rams		
	actual	theoretical	actual	theoretical	actual	theoretical
I (Sheep № 483)						
At birth	4.00	4.90	-0.90	5.06	6.13	-1.07
4	27.4	24.6	2.80	38.4	34.7	3.65
6	36.1	36.2	-0.09	52.6	53.7	-1.14
8	40.0	44.5	-4.35	64.0	68.5	-4.48
12	52.9	50.9	2.01	83.6	80.7	2.84
15	56.7	56.2	0.53	91.6	91.4	0.19
II (Sheep № 256)						
At birth	4.0	4.9	-0.91	4.62	5.6	-1.04
4	26.4	23.7	2.67	36.7	33.2	3.47
6	35.3	35.0	0.28	51.1	51.9	-0.86
8	39.0	43.2	-4.18	62.0	66.7	-4.70
12	50.7	49.6	1.08	82.1	79.1	2.98
15	56.0	54.9	1.05	90.1	89.9	0.14
III (Sheep № 628)						
At birth	3.6	4.4	-0.82	4.4	5.3	-0.97
4	25.3	22.8	2.52	35.7	32.5	3.16
6	33.7	33.9	-0.16	50.5	51.0	-0.54
8	38.6	41.9	-3.32	61.0	65.6	-4.60
12	49.2	48.3	0.89	80.6	77.9	2.73
15	54.5	53.6	0.89	88.8	88.6	0.21

V: *Coefficients of growth models of young animals of the studied groups*

Group		Model by B. Gompertz			Model by Z. Guo and G. Svolva		
		A_0	α	R^2	a	b	c
I (Sheep № 483)	ewe lambs	1,25	2,64	97,64	3,98	0,92	27,87
	rams	2,03	2,33	98,55	-23,71	29,85	23,44
II (Sheep № 256)	ewe lambs	1,35	2,49	97,71	1,22	3,69	24,94
	rams	1,99	2,28	98,57	-28,75	34,41	19,22
III (Sheep № 628)	ewe lambs	1,19	2,56	98,01	-0,19	4,61	23,72
	rams	1,86	2,33	98,61	-28,77	34,09	18,89

The average level of deviations of the actual from the theoretical weight was marked by age periods at birth, 4, 8 months. And the best reliability was inherent at the age of 6 months.

A number of scientists point out that the creation of new highly productive herds of animals is impossible without an assessment of breeding objects at an early age, as well as at different stages of their development. Therefore, much attention is paid to mathematical modeling and forecasting of future productivity, as well as to identifying the difference between the actual and theoretical amount of products received.

Thus, Japanese scientists S. Yamaguchi, T. Kawahara, Y. Goto, Y. Masuda, M. Suzuki confirmed that the model of Z. Guo and G. Svolva, forming a theoretical growth curve, highly adequately determines the actual monthly growth, and in within each experimental group, the approximation coefficient was at least 81.54%, which is a high indicator (Satoshi Yamaguchi *et al.*, 2007).

And T. Landete-Castillejos and L. Gallego adapted mathematical models based on linear least squares regression to growth rates. And they divided the models into two types: a peak (standard) growth curve, called type I, and a continuously decreasing growth curve, called type II. The model of Z. Guo and G. Svolva turned out to be an inverse polynomial model and always modeled type I curves (Landete-Castillejos and Gallego, 2000).

Analyzing the main coefficients of growth models (Tab. V), it could be noted that the ewes of the second group are characterized by a more intense initial growth rate of the theoretical growth curve - A_0 = 1.35 compared with peers of the other two experimental groups, and in the case of rams, the leaders representatives of the first group with the indicator - A_0 = 2.03.

As for the speed of maturation, the representatives of the first group had an advantage with an indicator of α = 2.64, in which it surpassed the other two experimental groups, and in the case of rams, more intensive growth with an indicator of α = 2.33 was inherent in the rams of the first and third experimental groups. Approximation of the actual curves by the theoretical ones showed that the highest value of the coefficients of determination within the framework of the model used were inherent in the representatives of the third group - R^2 = 98.01 for ewes and R^2 = 98.61 for rams.

The second no less important way to characterize the coefficients of growth models of young animals of the studied groups using the methods of mathematical modeling and predicting future productivity, as well as identifying the difference between different groups of sheep, in terms of the obtained products, is to use the model of Z. Guo and G. Svolva.

As a result of the research, it was found that among the young sheep of the Ascanian fine-wool breed, according to the model constants, the highest maximum possible increase (*a*) ♀ 3.98, ♂ 23.71, and the level of decline (*c*) of the growth curve ♀ 27.87, ♂ 23, 44 had representatives of the first experimental group. As for the constants characterizing the intensity of the rise (*b*), the best was observed in the animals of the second group - ♀ 3.69, ♂ 34.41.

T. G. Jenkins, K. M. Rolfe, W. M. Snelling, C. L. Ferrell also used growth constants in their studies, while analyzing the actual weight and linear corrected weight during the growth period of bulls of different breeds. An assessment of the genetic correlation between growth constants showed sufficient direct genetic variability. This will allow selection to change the shape of the growth curve and increase animal productivity (Rolfe *et al.*, 2011).

Non-linear model parameters for biological interpretation can be used to calculate robust estimates of growth traits such as maximum or average postnatal growth rate. T. V. Orikhivskyi, V. V. Fedorovych & N. P. Mazur, confirm that current models with variable inflection points are able to adequately describe growth in a wide variety of animals, fit a set of data showing sigmoidal growth patterns, and provide satisfactory feature scores for quantifying growth characteristics of different animal species (Orikhivskyi *et al.*, 2019).

CONCLUSION

Calculations of the entropy-information analysis of live weight and wool length showed that the young stock of the Askanian fine-wool breed, in terms of the level of organization of systems, was characterized by ambiguous data on the organization of the system and relative entropy, which indicates sufficient disorganization of the system and provides opportunities for selection, has the potential to increase productivity. At the same time, sexual demorphism in the manifestation of signs of entropy was revealed, so the ewes of all experimental groups tended to reduce the level of unconditional entpropy.

And the use of genetic and mathematical modeling showed a clear advantage in live weight of ewes and rams, which were the descendants of the first sire No. 483, which can characterize him as a carrier of the best hereditary characteristics regarding the ability to transmit high productive traits to the next generations. The B. Gompertz model is one of the most effective and modern approaches describing the dynamics of live weight gain in young sheep, which can serve as a kind of marker in predicting the productive qualities of animals. At the same time, the model of Z. Guo and G. Svolva, forming a theoretical curve of live weight change, highly, adequately determines the actual monthly gains. The formation of the growth variability curve and its main parameters (a, b, c) in young sheep still depends to a greater extent on the origin and genetic characteristics of the animal than on age. This gives grounds to assert that the genetic component is the main criterion for selection and breeding work and its further economic and technological use.

When using a mixed biometric model, among the studied groups, according to the dynamics of changes in the main breeding traits of young sheep, it was found that, according to the degree of development of live weight, indicators of wool productivity, growth and development characteristics, the sheep of the first group turned out to be the best, regardless of their sexual dimorphism, which indicates a high genetic potential of ram No. 483. Which will make it possible, when using it, to reduce the cost of sheep breeding products by increasing productivity and improving the quality of wool in its descendants.

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Contact information

Olena Karatieieva: karateeva1207@gmail.com (corresponding author)
Vadim Posukhin: vadimposuhin@gmail.com