CHARACTERISTICS OF THE POPULATION OF THE YAROSLAVL BREED OF CATTLE BASED ON THE ASSESSMENT OF POLYMORPHISM OF EAB - LOCI

A V Ilina, E G Evdokimov, M V Abramova, A V Konovalov

Federal Williams Research Center of Forage Production & Agroecology, Yaroslavl Scientific Research Institute of livestock breeding and forage production, Lenin street, b.1, Mikhailovsky settlement, Yaroslavl region, Russia

Corresponding author e-mail: annabilina@yandex.ru

Abstract. The paper presents the characteristics of micropopulations of the Yaroslavl cattle breed based on the assessment of the polymorphism of the EAB-locus of blood groups. The presented dendrogram made it possible to identify the farms most distant from the main group. To identify the closest and most distant groups of animals, the Euclidean distance was calculated. The efficiency of division into groups was assessed using the Davis-Boldin index, which made it possible to distribute the population into three clusters with the most optimal value, where each group obtained has its own parent population from which it developed. Key words: cattle, Yaroslavl breed, genetic diversity, frequency of occurrence, indices of population structure, genotypic heterozygosity, clustering.

1. Introduction
For practical breeding from the point of view of population genetics and preservation of the gene pool of valuable genotypes, the intraspecific biological diversity of cattle breeds plays a significant role [1].

The breeding qualities of animals are determined by its genotype, since they are determined by a whole complex of inherited genes. The study of immunogenetic indicators provides an objective assessment of the breeding qualities of animals [2,3].

Genetic labeling of animals by blood groups is used in cattle breeding to confirm certain tasks: control of the reliability of records of origin in pedigree documents; in determining the similarities and genetic differences between individual animals, lines and families, herds and breeds; to improve reproductive abilities, increase the level of productivity, preserve and control the transmission of valuable animal genotypes in generations, predict the effect of heterosis; selection of parental pairs in order to obtain animals of the desired genotypes, as well as for the examination of the breed of animals [4,5,6,7,8].

2. Materials and methods
The paper presents the allele pool of the Yaroslavl breed according to the EAB - loci of blood groups of pedigree farms in the Yaroslavl region, based on immunogenetic parameters.

The study and analysis of the allele pool for the EAB - loci in the herd was carried out in the period 2015-2019.
The analysis of the allele pool for the EAB - loci was carried out on 6343 heads of cattle of the Yaroslavl breed in the laboratory of genetics and biotechnology of the Yaroslavl NIIZhK - a branch of the Federal Research Center "VIK im. VR Williams ".

The work carried out statistical calculations: the frequency of occurrence of EAB - loci in each group of animals [9], the number of effective alleles in the herd [9], Euclidean distance [10], clustering by the k-means method [10], Davis-Boldin index [10]...

Principal component analysis for the available sample was performed in Python using the "sklearn" package. To process the data obtained, the following software programs were used: MS Office Excel, Python 3.7.0, Statistica 10, past 3.

3. Results and discussion
The most objective characterization of genetic variability in groups of animals is provided by the alleles of the EAB - loci, therefore, they are used to assess the hereditary characteristics of animals. The gene pool structure of each micropopulation has significant differences in loci and their frequencies in the breed population.

According to the obtained frequencies of antigen carriers using the UPGMA method, the cows were divided into groups and a dendrogram was built.

The obtained dendrogram clearly shows that LLC Plemzavod im. Dzerzhinsky "and CJSC" Agrofirma "Pakhma", as they are the most distant from the main group of farms.

The main cluster is formed by two subgroups of farms: the first subgroup of JSC Yaroslavsky Broiler, JSC Plemzavod Yaroslavka, CJSC Novy Put, LLC Shopsha and the second subgroup of LLC Novaya Zhizn, CJSC Tatishchevskoe, LLC Agrotsekh , LLC "Melenkovsky". The intermediate position is occupied by the SPK collective farm "Progress" and the PSHK "Iskra" (Fig. 1a).

The genetic distance according to Nay, calculated from the frequency indices, makes it possible to assess the degree of kinship of animals and to reveal their kinship ratio of different groups [11, 12]. The data obtained for the studied farms give a similar picture to the above-described results for the Euclidean distance, but there are also significant changes.

Based on the calculated indicator, two main subgroups can be distinguished that are closest to each other in terms of genetic distance: the subgroup of OOO Novaya Zhizn, SPK collective farm Progress, OOO Shopsha and the subgroup of PSHK Iskra, OOO Melenkovsky, ZAO Novy way "", JSC“ Yaroslavl Broiler ”, JSC“ Plemzavod “Yaroslavka”, LLC “Agrotsekh”, CJSC “Agrofirma“ Pakhma ”. For these groups, the smallest genetic distance is observed (up to 0.029*10^-4) (fig. 1b).
Herds of JSC "Plemzavod im. Dzerzhinsky" and JSC "Tatishchevskoye" are the most distant from other farms. This distance ranges from $0.03 \times 10^{-4}$ to $0.083 \times 10^{-4}$. The distance between these farms is $0.066 \times 10^{-4}$, which indicates significant genetic differences between the populations of these farms. Thus, there are three main clusters into which the Yaroslavl cattle population can be decomposed.

According to the Davis-Boldin index, the population of cattle of the Yaroslavl breed was divided into three clusters, each group obtained has its own ancestral population from which it developed. For each group, you can describe your "immunogenetic portrait" (Table 1).

| Clusters | Farms | Unique alleles |
|----------|-------|----------------|
| JSC Plemzavod | B$_2$O$_2$:B', B$_2$O$_2$:Y$_2$, B$_2$Y$_2$:A'3:$l'P'Q'Y'$, B$_2$Y$_2$:E':G'$, O$_2$:Y$_2$, O$_2$:Y$_2$:A', Y$_2$:A'2:J'K'O', Y$_2$:D'E', B'E':G', B$_2$:G$_2$:Y$_2$:A', B$_2$:O$_2$:Y$_2$, B$_2$:O$_2$:Y$_2$:A', B$_2$:O$_2$:Y$_2$:A', B$_2$:O$_2$:Y$_2$:A', |
| Yaroslavka, CJSC | O$_2$:Y$_2$:E':D'G'F', O$_2$:A'2:J'K'O', Y$_2$:D'E', B'E':G', |
| Tatishchevkoye, | D'E':Y':G'O', E':Q', E':G', B$_2$:G$_2$:Y$_2$:A', B$_2$:O$_2$:Y$_2$, |
| JSC Yaroslavsky | B$_2$:O$_2$:A':E':P'Q', B$_2$:O$_2$:Y$_2$:A':E':G'O'G', B$_2$:Y$_2$:A':E':P'Q'Y', A':O', B$_2$:A':2:O', G$_2$:O$_2$:E':Q', O$_2$:Y$_2$:E':Q', Y$_2$:D'E', B$_2$:O$_2$:A':E':P'Q', |
| Broiler, LLC | B$_2$:O$_2$:Y$_2$, G$_2$:A':O', G$_2$:O$_2$:E':Q', Y$_2$:D'E', B$_2$:O$_2$:A':E':P'Q', |
| Agrocekh, SPK | B$_2$:Y$_2$:A':E':G'G', B$_2$:Y$_2$:A':E':P'Q', B$_2$:Y$_2$:G':P':Q'Y', G$_2$I'A', |
| collective farm | G$_2$:O$_2$:E':Q', G$_2$:O$_2$:A', G$_2$:A':E':I'K'O', |
| Progress, LLC | Y$_2$:D'E':F'G'O', B'E':G', E':F'G'O'G', O$_2$:A':D'F'G', B'E':I'G', |
| Novaya Zhizn, LLC | Y$_2$:E'G'G', B$_2$:Y$_2$:A':P'Q'Y', O$_2$:J'K'O', O$_2$:A':I', Y$_2$:E'G', |
| Melenkovsky, | B$_2$:Y$_2$:E'G'Y', O$_2$:A'E':D'F'G', O$_2$:D'E':F'G'O'G', B$_2$:O$_2$:A'I'P'G', |
| PSHK Iskra, CJSC | G$_2$:Y$_2$:O', O$_2$:A':J'K'O', O$_2$:D'E':F'G'O', O$_2$:A', P$_2$:E'I', |
| Novy Put, LLC "Shopsha" | Y$_2$:E'F'G'O'G', E'2, B$_2$:G$_2$:O$_2$:E':O', B$_2$:Y$_2$:A':I'P'Q', G$_2$:Y$_2$:D', Y$_2$:G'G', D'C'O', D'E'G' |
| I | CJSC "Agrofirma" Pahkma " | B$_2$:G$_2$:O$_2$, B$_2$:G$_2$:E':3, B$_2$:I', B$_2$:O$_2$:B', B$_2$:O$_2$:Y$_2$:D', B$_2$:Y$_2$:E':G'Y', B$_2$:Y$_2$:I'1'A':P'Q'Y', B$_2$:I'P'Q'Y', B$_2$:I'P'Q'Y', G$_2$:O$_2$:D'Q', G$_2$:E':2, G$_2$:Y$_2$, G$_2$:Y$_2$:E':3Q', O$_2$:A'2, O$_2$:D', O$_2$:D'E':F'G'O', O$_2$:Y$_2$:A'I', Y$_2$:E'F'G'O', O$_2$:A':E':D'G'F', P$_2$:I', Y$_2$:A'2, Y$_2$:D'E', Y$_2$:G'G', Y$_2$:Y', B'E':G', D'E':F':G'O', D'E':G', D'G'O', E'G', E'Q', G', Q', G' |
| II | JSC Plemzavod im. Dzerzhinskiy " | B$_2$:O$_2$, B$_2$:O$_2$:Y$_2$:A':E':E':P'Q'G"", B$_2$:O$_2$:Y$_2$:A':E':E':P'Q'G"", B$_2$:O$_2$:I'1", B$_2$:O$_2$:A':E':E':P'Q'G"", B$_2$:O$_2$:D', B$_2$:G$_2$:O$_2$:Y$_2$, B$_2$:Y$_2$:A':E':E':G'P", I$_2$:O$_2$, O$_2$:E', O$_2$:E':G'G", O$_2$:I', O$_2$:Q', O$_2$:Y$_2$:D', O$_2$:Y$_2$:E'F'G'O'G", P$_2$:A'2G', QE'3, Y$_2$:D', Y$_2$:D'E':1, Y$_2$:G"2, A':2', A':2G', A':2G", A':3I', A':2Q', D'E':F'G'O', E'1Q', E'2', Q'T" |

The following antigens are common to farms B$_2$:O$_2$, G$_2$:O$_2$, G$_2$:O$_2$:A', G$_2$:O$_2$:Y$_2$, I, I$_2$, O$_2$, Y$_2$, b, O$_2$:E', G"", E'3G"."

Considering a significant number of variables, to visualize the data obtained, the possible options were reduced to three using the principal component analysis (PCA) (Fig. 2).

Most of the farms are in one group and form two previously described subgroups: the subgroup of JSC Yaroslavsky Broiler, JSC Plemzavod Yaroslavka, CJSC Novy Put, LLC Novaya Zhizn, LLC "Yaroslavl", the subgroup of CJSC Tatishchevskoe, LLC "Agrotsekh", LLC "Melenkovsky", PSHK "Iskra".

Farms of the SPK collective farm "Progress", JSC Yaroslavsky Broiler, JSC Plemzavod im. Dzerzhinskiy "are separate and form three independent populations of animals. The division into groups indicates the presence of several independent ancestral lines from which the populations of the studied farms developed."
Figure 2. Decomposition of farms in three-dimensional space based on antigen frequencies.

To identify the genetic characteristics of a population, population indices and indices of genetic diversity, shown in Table 2, are widely used.

Table 2. Population structure indices of farms by Yaroslavl breed of cows

| Farms                  | Average per locus index of information Shannon I (m±se) [Lewontin, 1972] | Average number of alleles μ, (m±sμ) [Zhivotovsky, 1991] | Proportion of rare alleles, hμ (m±sh) [Zhivotovsky, 1991] | Average per locus gene diversity, Ht (m±se) [Nei, 1987] |
|------------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|---------------------------------------------------------------|------------------------------------------------------------|
| LLC "Agrotsekh"        | 0,0192±0,0002                                                               | 1,0664±0,0036                                                                                   | 0,9971±0,0025                                                  | 0,0109±0,0021                                              |
| JSC “Plemzavod im. Dzerzhinsky " | 0,0234±0,0003                                                               | 1,0799±0,0043                                                                                   | 0,9961±0,003                                                   | 0,0145±0,0030                                              |
| LLC "Melenkovsky"     | 0,0184±0,0003                                                               | 1,0641±0,0035                                                                                   | 0,9971±0,0024                                                  | 0,0108±0,0024                                              |
| LLC "New Life"        | 0,0172±0,0003                                                               | 1,0577±0,0031                                                                                   | 0,9971±0,0022                                                  | 0,0106±0,0026                                              |
| CJSC "New Way"        | 0,0173±0,0003                                                               | 1,0589±0,0032                                                                                   | 0,9971±0,0022                                                  | 0,0106±0,0026                                              |
| CJSC "Agrofirma Pakhma " | 0,0206±0,0002                                                               | 1,0784±0,0042                                                                                   | 0,9971±0,0030                                                  | 0,0110±0,0020                                              |
| SPK collective farm "Progress" | 0,0172±0,0003                                                               | 1,0604±0,0033                                                                                   | 0,9971±0,0023                                                  | 0,0105±0,0027                                              |
| LLC "Shopsha"         | 0,0164±0,0003                                                               | 1,0543±0,0029                                                                                   | 0,9971±0,0021                                                  | 0,0105±0,0028                                              |
| JSC Plemzavod Yaroslavka | 0,0175±0,0003                                                               | 1,0604±0,0033                                                                                   | 0,9972±0,0023                                                  | 0,0106±0,0025                                              |
| JSC "Tatishchevskoe"  | 0,0163±0,0003                                                               | 1,0521±0,0028                                                                                   | 0,9971±0,0020                                                  | 0,0105±0,0027                                              |
| PSHK Iskra            | 0,0192±0,0003                                                               | 1,0624±0,0034                                                                                   | 0,9969±0,0024                                                  | 0,0116±0,0024                                              |
| JSC "Yaroslavl Broiler" | 0,0174±0,0003                                                               | 1,0597±0,0032                                                                                   | 0,9971±0,0023                                                  | 0,0106±0,0026                                              |

Designations: se–Standard error; sμ – allele mean error; sh – error in the proportion of rare alleles.

The parameters of genetic diversity make it possible to assess the state of the population and to characterize the effectiveness of selection effects on animals. Thus, low indices of polymorphism of
loci, index of gene diversity and Shannon I index may indirectly indicate the presence of inbred depression or a pronounced effect of artificial selection [13]. Genetic diversity according to Ney and Shannon shows genotypic hetozygosity within a population and indicates the presence of different alleles in a population. Among the studied populations, the least diversity, about 0.0105 H and 0.0165 I, SEC collective farm "Progress", LLC "Shopsha" and JSC "Tatishchevskoe", and the largest JSC "Plemzavod im. Dzerzhinsky " (0.0145 H and 0.0234 I), which indicates a difference in the selection effect. But it is worth noting that the total genetic diversity varies from 0.0105 H to 0.0145 H and from 0.0163 I to 0.023 I, which is low and indicates artificial selection and breeding activities [13].

Intrapopulation diversity can also be described using the average number of alleles and the proportion of rare alleles [9]. The average number of alleles reflects the degree of diversity, and the proportion of rare alleles is the uniformity of their distribution. In the studied populations, approximately one level of uniformity in the distribution of allele frequencies is observed ($\mu = 1.0629$ and $h\mu = 0.9970$) and at the same time is very low, i.e. alleles in populations are very unevenly distributed.

Thus, it can be noted that JSC Plemzavod im. Dzerzhinsky "and CJSC" Agrofirma "Pakhma" have higher values in the average genetic diversity, average per locus the Shannon Information Index, which indicates differences in breeding work in these farms and the possible use of animals from these farms to increase genetic diversity in other farms.

4. Conclusion
The management of genetic resources depends on monitoring the allele pool of a population. In-depth genetic analysis of animals by immunogenetic markers allows you to control the level of genetic homogeneity and, when matching, remove the effect of increasing "intrabreed inbreeding" (homozygosity) in a herd, which is close in importance to an increase in inbreeding, with all its negative consequences. The genetic improvement of a population and its prediction in large-scale selection depends on the intensity of selection of sire and mother of bulls.

Acknowledgments
This work was supported by the Ministry of Science and Higher Education on the topic "To improve the methods of genetic control and management of the breeding process, the technology of feeding and keeping cattle and sheep in order to increase the productivity and profitability of livestock production" (No. 0597-2019-0016-C- 01). Registration number AAAA-A18-118072590036-2.

References
[1] Kiseleva T.Yu., Podoba B.E., Zabludovsky E.E. et al. 2010 Analysis of 30 microsatellite markers in six local populations of cattle Agricultural Biology No. 6 pp. 20-26
[2] Ernst L.K., Zinovieva N.A. 2008 Biological problems of animal husbandry in the XXI century M.: RAAS 508 p.
[3] Bugaev S.P., Volobuev V.V. 2016 Immunogenetic markers of milk productivity in the selection of cattle of dairy and combined breeds Bulletin of the Kursk State Agricultural Academy No. 9 pp. 1-6
[4] Gontov M.E., Koltsov D.N., Onufriev V.A. 2017 Allel pool of cattle of the pedigree reproducer of JSC "Smolenskoye" and its use for the examination of the breed belonging Kaluga pp. 184-188
[5] A. A. Novikov 2015 Recommendations for the use of genetic monitoring methods in the breeding of cattle and pigs Lesnie Polyan 23 p.
[6] Deeva V.S., Labuzova I.M., Shefer N.A. et al. 2007 Allelo pool of Irmen type black-and-white cows by blood groups and their association with productive ones. SPb. : VNIIGZH. pp. 234-237
[7] Ilyina A.V. 2018 Allel pool of cattle of the Yaroslavl breed according to the EAB locus of the herd of LLC "Agrocekh" of the Yaroslavl region Multifunctional adaptive fodder production Moscow Pp. 104-108

[8] Ilyina A.V., Khurtina O.A. 2019 Immunogenetic monitoring in work with cattle Integration of science and higher education as the basis for innovative development of agricultural production Yaroslavl: Chancellor pp. 66 – 67

[9] Zhivotovsky L.A. 1991 Population biometrics Moscow: Nauka 271 p.

[10] Mozokhin D.E., Kalyagin V.A. 2015 Comparative analysis of clustering algorithms in networks of stock markets Algorithms, methods and data processing systems 4 (33) P. 73-90

[11] Nei M. Analysis of Gene Diversity in Subdivided Populations 1973 Proc. Natl. Acad. Sci. USA. V.70. No12. P. 3321-3323

[12] Lewontin R. C. 1972 The apportionment of human diversity Evol. Biol. No 6 P. 381–398

[13] Stolpovsky Yu.A., Kol N.V., Evsyukov A.N., Ruzina M.N., Shimit L.V., Sulimova G.E. 2010 Analysis of the genetic structure of Tuvan short-fat-tailed sheep populations using the ISSR-PCR method Genetics V. 46 No. 12 pp. 1660-1669