Genetic structure of population of the Kalmyk breed cattle

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Abstract. Blood groups, due to their irremovability and independence from gender, age, feeding conditions and maintenance, are widely used in animal breeding. The purpose of this study was to identify genetic markers of economically valuable traits of cattle of Kalmyk breed. Analysis of polymorphism of blood groups of Kalmyk cattle during the study period showed that there are antigens in the allelofond with a high concentration and frequency of occurrence: A1, A2, D', W, V, and Z, while G2I', C2 remain with low one. Analysis of the genetic status of different breeds revealed that there are obvious differences in frequencies. Antigens A1,A2,E'3,Z can serve as genetic markers of Kalmyk cattle purebred. The highest index of genetic distance was 0.1931 between the Kalmyk breed of the Republic of Kazakhstan and the Kazakh white-headed breed. The smallest genetic distance was found between the Simmental breed and the Kalmyk AO and is equal to 0.1166.
The identification of the most effective method of selection, taking into account the index of genetic similarity, revealed the smallest number of parent pairs in the low (0.0-0.30) and high (0.61-0.90) indices of antigenic similarity and amounted to: "Agrofirma Aduchi" LLC – 24 pairs (16%) and 48 pairs (32%), "Sarpa" AO – 17 pairs (11%) and 21 pair (14%), A. A. Chapchayev AO PZ – 15 pairs (10%) and 9 pairs (6%), "Agribusiness" LLC – 8 pairs (5%) and 7 pairs (5%), respectively. When selecting parent pairs with an antigenic similarity index of 0.31-0.60, it allows to get bullheads with the highest live weight. Antigens marking the index value of 0,31-0,60, A1, A2, G2, E'3, C2, Z are considered genetic markers of the reproductive ability of Kalmyk breed cattle.

1 Introduction

In modern selection and breeding work, the study and use of immunogenetic indicators of animals is important, since it gives an idea of the genetic structure of the population and subsequently allows purposefully conducting breeding work with them.

The study of polymorphism of blood genetic systems is relevant and accessible. Genetic labeling of economically valuable traits allows comparing livestock populations by the level of biological diversity, monitoring the gene pool of any breed, evaluating and predicting the effectiveness of selection and breeding work.

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2 Materials and methods

The object of the study was Kalmyk breed cattle from 11 breeding farms of the Republic of Kalmykia (quantity of heads n>2000). The research material is biological material (blood with anticoagulant). Blood groups were determined by standard serologic tests (according to Neimann-Sorenson) using 30 monospecific serums, which were produced in JSC "Samarskoye" for breeding work. The frequency of occurrence of antigens was calculated by the formula:

$$P = \frac{n}{N}, \quad (1)$$

where n is the number of antigen carriers,
N is the total number of animals.
A total of 7 blood group systems were tested.
Genetic distances were calculated using M. Ney's formula:

$$D_N = -\ln I_N; \quad (2)$$

$$I_N = \sum\sum_{ij} Y_{ij} / \sqrt{\sum\sum_{x^2ij}} * \sum\sum_{y^2ij}, \quad (3)$$

where I_N is the coefficient of genetic similarity,
x and y are the frequency of occurrence of antigens.
The index of antigenic similarity of parents was calculated using the following formula:

$$a = \frac{S}{n1+n2-S} \quad (4)$$

where S is the number of similar antigens in bulls and cows;
n1 is the number of identified antigens in bulls;
n2 is the number of detected antigens in cows.

The animals were divided into groups 0-30; 0.31–0.60; 0.61–1.00, based on the index of antigenic similarity of parents. Each group was weighed at the age of 205 days, 12 months, 15 months. According to the data obtained, the average daily increase in these periods was calculated.

The aim of the study was to identify genetic markers of economically valuable traits of cattle of Kalmyk breed. In this regard, the following activities were carried out: monitoring of changes in the frequency of occurrence of blood antigens of Kalmyk cattle in breeding farms of the republic over the past 10 years, characterisation of genetic polymorphism of blood groups of cattle of different breeds and their comparison, identification of genetic distances between breeds, identification of the most effective method of selection taking into account the index of genetic similarity.

3 Results and discussion

The frequency of occurrence of erythrocyte antigens shows that the concentration of A1 and A2 in the EAA system remains at a consistently high level. The highest frequency of A2 antigen was observed in 2009-2010 (73%). In the EAB system, there is a change in the frequency of occurrence in most of the antigens. The frequency of B2 antigen increased from 29% to 66%, I1 – from 19% to 35%, O2 – from 22% to 66%, Y2 – from 23% to 48%, E'3 – from 41% to 87%, F' – from 24% to 57% and O' – from 31% to 62%. A low threshold of frequency concentration in the AB system is observed in the O4 antigen (47% and 29%). Antigens with a constant concentration are observed (D', Q'). The EAC system shows an increase in the concentration of C1 and R2 antigens - from 36% to 79%, from 17% to 29%,

respectively. Low concentration of occurrence frequencies in X2 is from 61% to 45% and L', from 26% to 13%. The frequency of occurrence of the W antigen remains unchanged.

Table 1. Monitoring of the gene pool in breeding farms of the Republic of Kalmykia.

System	Antigens	Average indicators of the frequency of antigens in breeding farms of the Republic of Kalmykia	
		2009-2010	2020-2021
EAA	A1	0.57	0.69
	A2	0.73	0.69
EAB	B2	0.29	0.66
	G2	0.26	0.36
	I1	0.19	0.35
	O2	0.24	0.66
	O4	0.47	0.29
	Y2	0.23	0.48
	D’	0.49	0.44
	E’3	0.41	0.87
	F’	0.24	0.57
	I’	0.29	0.35
	O’	0.31	0.62
	Q’	0.42	0.46
EAC	C1	0.36	0.79
	C2	0.34	0.26
	R2	0.17	0.29
	W	0.61	0.67
	X2	0.61	0.45
	L’	0.26	0.13
EAF-V	V	0.47	0.49
EAJ	J	0.10	0.43
EAS	S1	0.26	0.53
	H”	0.44	0.46
	U”	0.03	0.49
EAZ	Z	0.79	0.73

The concentration of antigen V frequency remains stable - 47% in 2009-2010 and 49% in 2020-2021. At the same time, an increase in the frequency of antigen J from 10% to 43% was revealed. In the EAS system, there is an accumulation of the concentration of antigens S1 (26% - 53%), U” (3% - 49%). The Z antigen remains constant throughout the study period. Analysing the data, we offer recommendations on the exchange of breeding material between farms, depending on the concentration of the frequency of antigens in herds.

Immunogenetic examination of the Kazakh white-headed, Simmental, Hereford and Kalmyk breeds of the Astrakhan region (Table 2) showed certain differences. Thus, the Kazakh white-headed breed had a high frequency of occurrence of antigens A1, I', C1, W, L, F, and the lowest S, G3, O3, F', Q, U". Antigens O2, Y2, C2, X2, H" were not detected. The concentration of erythrocyte antigens is high in Hereford cattle G2, O3, Y2, C2, L, V, and low in A1, B2, I1, I', R2, H”.

Table 2. Comparative characteristics of the allele pool of cattle of different breeds.

System	Antigene	Kalmyk n- 1918	Kazakh whitehead n-200	Hereford n-50	Simmental, n-50	Kalmyk (Astrakhan region), n-70
Frequency of occurrence, %						
EAA	A1	67	63	18	43	61
	A2	66	45	29	66	98
EAB	B2	69	20	15	0	20
	G2	27	28	69	39	20
	G3	35	11	24	14	9
	I1	33	50	14	12	7
	A'2	32	49	25	0	9
	O2	64	0	30	40	0
	O3	23	17	65	39	0
	O4	23	21	58	0	7
	Y2	43	0	67	77	20
	B'	15	40	20	0	30
	D’	61	55	26	17	21
	E’3	82	22	22	30	92
	F'	60	11	24	11	7
	I’	32	79	17	0	0
	O’	62	27	55	22	50
	Q	0	17	61	0	0
EAC	C1	88	73	35	91	32
	C2	17	0	72	0.94	11
	R2	29	50	13	20	94
	W	67	66	21	0	50
	X2	43	0	59	14	22
	L	20	91	71	23	90
EAF-EAV	F	19	87	47	9	71
	V	49	19	68	28	33
EAS	S1	41	33	46	13	0
	H”	41	0	18	65	40
	U”	55	12	21	0	30
EAZ	Z	71	40	25	25	99

The Simmental breed had the highest frequency of occurrence of A2, Y2, C1, C2, F, H antigens. The lowest concentration of frequencies was detected in G3, I1, D', F', X2, such antigens A'2, O4, I', W, U” were not detected. The analysis of cattle of the Kalmyk breed of the Astrakhan region revealed the maximum frequency of occurrence of antigens A2, E'3, R2, L, F, Z. Antigens I1, A'2, C2, D' were detected with the lowest frequency; antigens O3, I', Q, S1 were not detected. Antigens with the highest concentration of antigens were detected in the Kalmyk breed and in others. A1 occurs with the greatest frequency in the Kalmyk breed of Kalmykia (67%), Kazakh white-headed (63%) and Kalmyk AO (60%). A2 has the highest frequency in the Kalmyk breed of RK (66%), Simmental (66%) and Kalmyk AO (98%). In B2, O2, D', F', O', c are most common only in the Kalmyk breed of Kalmykia. The concentration of G2 and O3 is high in the Hereford breed - 69%, 65%, respectively. The greatest variation of the I' antigen was observed - in the Kazakh white-headed is 79%, in the Simmental and Kalmyk AO, the antigen was not detected. Q was detected only in the Kazakh white-headed (17%) and Hereford (61%) breed. The incidence of C1 antigen is high in Kalmyk (88%), Kazakh white-headed (73%), Simmental (91%), Hereford and Kalmyk AO, it is 35% and 32%, respectively. The differences of the R2 antigen are in its high concentration only in the Kalmyk AO breed (94%), the other breeds do not exceed 50%. The W antigen is found in the Kalmyk breed of the RK (67%) and the Kazakh white-headed breed (66%), which is the maximum indicator. The concentration of L is high in the Kazakh white-headed (91%), Hereford (71%), Kalmyk AO (90%) breeds. Thus, antigens A1, A2, E’3, O’, Z, which were found with high concentrations in both cattle of the RK and AR, can be recommended as markers of purebred Kalmyk breed.

The selection of parental pairs using blood groups was carried out in four breeding farms of the Republic of Kalmykia. According to the blood groups of bulls and cows,

antigenic similarity indices were found in the range from 0 to 1 (Fig. 1). Analysis of the distribution of possible variants of parental pairs revealed that the maximum number of variants was in the range of 0.31 - 0.60 and amounted to: parents in the selection option of "Agrofirma Aduchi" LLC - 102 pairs (68%), "Sarpa" AO - 112 pairs (75%), A. Chapchayev AO PZ – 126 pairs (84%), "Agribusiness" LLC - 135 pairs (90%).

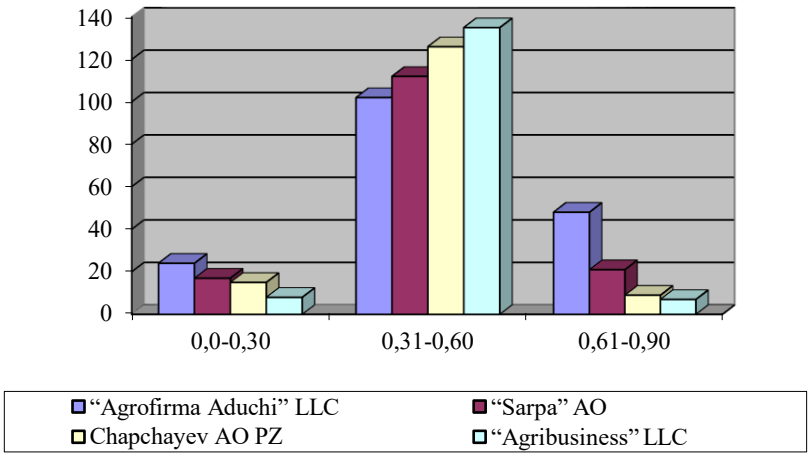

Fig. 1. Variants of parental pairs depending on the value of the antigenic similarity index.

Significantly less number of parent pairs is observed in low (0.0-0.30) and high (0.61-0.90) indices of antigenic similarity and amounted to: "Agrofirma Aduchi" LLC - 24 pairs (16%) and 48 pairs (32%), "Sarpa" AO - 17 pairs (11%) and 21 pairs (14 A. Chapchayev AO PZ – 15 pairs (10%) and 9 pairs (6%), "Agribusiness" LLC - 8 pairs (5%) and 7 pairs (5%), respectively. The effect of the value of the index of genetic similarity of parental pairs on the live weight of offspring is as follows (Table 3):

Table 3. Dynamics of live weight of bullheads obtained from parent pairs with different genetic similarity index.

Index value		Live weight, kg		
	n	205 days	12 months	15 months
"Agrofirma Aduchi" LLC				
0.0-0.30	12	188.1±5.2	308.1±5.2	358.3±6.1
0.31-0.60	48	201.8±6.3	325.1±6.3^{x}	380.5±6.8^{x}
0.61-0.90	20	187.6±4.2	306.9±4.2	359.8±4.6
Total	80	196.2±5.5	318.0±5.5	372.0±6.1
"Sarpa" AO				
0.0-0.30	6	180.6±5.2	299.2±4.7	385.0±5.8
0.31-0.60	53	203.1±6.3^{xx}	319.3±4.3^{xx}	404.1±6.2^{x}
0.61-0.90	23	180.1±4.2	298.5±4.9	384.5±5.1
Total	82	195±5.5	312±4.5	397.2±5.9
A. Chapchayev AO PZ				
0.0-0.30	17	176.2±5.2	293.7±5.3	357.4±5.4
0.31-0.60	57	191.2±6.3^{x}	314.2±5.1^{xx}	375.2±5.7^{x}
0.61-0.90	7	175.1±4.2	292.9±4.7	357.9±5.1
Total	81	185.1±5.5	308.0±5.1	370±5.6
"Agribusiness" LLC				
0.0-0.30	6	184.6±5.2	305.1±5.2	363.3±5.3
0.31-0.60	60	210.3±6.3^{xxx}	334.2±4.5^{xxx}	392.1±5.4^{xxx}
0.61-0.90	20	186.9±4.2	307.6±4.3	364.2±4.6
Total	86	201±5.5	322±4.5	380±5.2

^{x}-P>0.95 ^{xx}-P>0.99 ^{xxx}-P>0.999

The productive qualities of animals depend on the index of genetic similarity of parents, as shown by a comparative analysis of the live weight of bulls in different age periods. The largest live weight was obtained from bulls whose parents with an antigenic similarity index of 0.31-0.60, the difference between descendants with an index of 0.0-0.30 and 0.61-0.90 was 13.7 kg and 14.2 kg at the age of 205 days in "Agrofirma Aduchi" LLC, 22.5 kg and 23 kg in "Sarpa" AO (P>0.99), A. Chapchayev AO PZ 15 kg and 16.1 kg (P>0.95) and "Agribusiness" LLC 25.7 kg and 23.4 kg (P> 0.999). At the age of 12 months, the difference in live weight was: in "Agrofirma Aduchi" LLC 17 kg and 18.2 kg (P>0.95), "Sarpa" AO 20.1 kg and 20.8 kg (P>0.99), A. Chapchayev AO PZ 20.5 kg and 21.3 kg (P>0.99) and "Agribusiness" LLC 29.1 and 26.6 kg (P>0.999). In 15 months, these indicators amounted to 22.2 kg and 20.7 kg (P>0.95) in "Agrofirma Aduchi" LLC, "Sarpa" AO 19.1 kg and 19.6 kg (P>0.95), A. Chapchayev AO PZ 17.8 kg and 17.3 kg (P> 0.95) and "Agribusiness" LLC 28.8 and 27.2 kg (P> 0.999).

The obtained data on live weight showed that the animals of "Agribusiness" LLC had the greatest difference in distribution, taking into account the index of genetic similarity of parents (P>0.999). Bulls at the age of 15 months of the "Sarpa" AO farm had the largest live weight, but at the same time the difference between descendants from parents with different genetic similarity index is significantly less than in "Agribusiness" LLC. As a result, we state that the selection of pairs with an antigenic similarity index of 0.31-0.60 allows you to get bulls with the highest live weight.

The average daily increments of bullheads were calculated based on the results of weighing animals (Table 4). The analysis of the average daily increments of bulls revealed significant differences, where the advantage of young animals with an antigenic similarity index (ASI) in the value of 0.31-0.60 was observed. It was found that the average daily increase in live weight differs both by growth periods and by farms. The maximum values were found in bulls of the period from 8 to 15 months – from 976 to 789 g. The smallest values were found in the period from birth to 8 months of age – 627-742 g. The highest increase from 8 to 15 months was in the bulls of "Sarpa" AO - 957-976 g, the smallest increase in the bulls of A. Chapchayev AO PZ - 789-862 g.

Table 4. Average daily gains of bullheads with different genetic similarity index.

Index value	"Agrofirma Aduchi" LLC			"Sarpa" AO			A. Chapchayev AO PZ			"Agribusiness" LLC		
	Age, months											
	0-8	0-15	8-15	0-8	0-15	8-15	0-8	0-15	8-15	0-8	0-15	8-15
0.0-0.30	679	740	809	646	800	976	629	716	789	662	809	852
0.31-0.60	733	789	841	742	842	957	692	778	862	671	841	867
0.61-0.90	675	744	819	646	799	971	627	715	790	665	819	866

In the context of genetic similarity indices, the distribution of average daily gains revealed small contradictions. Bulls with an ASI of 0.31-0.60 of "Sarpa" AO had an average daily increase slightly lower than their peers with lower and higher ASI. In other groups, there was a tendency to higher rates in bulls with an average ASI. The largest difference was shown by the bulls of A. Chapchayev AO PZ (72-73 g), the smallest bulls of "Agribusiness" LLC. Thus, from the indicators that characterise the difference between bullheads with different IAS, bulls at the age of 15 months are preferable in terms of live weight. This is due to the fact that the main breeding sale is carried out at this age. Thus, the established difference in the live weight of bulls at 15 months of age with an ASI of 0.31-0.60 is reliable and can serve as a selection criterion.

A comparative analysis of the values of ASI with the frequency of occurrence of antigens was conducted (Table 5). It was found that with an index value of 0-0.30, S1, L, R2 antigens were found with the highest frequency in animals. With the value of the

antigenic similarity index, A1, A2, G2, E'3, C2, Z antigens had the highest concentration. At the maximum index value, antigens B', D', O', O2, G", W also occurred with the greatest frequency.

Table 5. Differentiation of antigen frequencies according to ASI.

Index value	Antigens with the most concentration
0.0–0.30	S1, L, R2
0.31–0.60	A1, A2, G2, E'3, C2, Z
0.61–0.90	B', D', O', O2, G", W

From the established data, it follows that for proper reproduction, it is necessary to select parent pairs with an antigenic similarity index not exceeding 0.31–0.60. Antigens A1, A2, G2, E'3, C2, Z are genetic markers of the reproductive ability of Kalmyk cattle.

4 Conclusion

In all breeding farms, there was an increase in the frequency of occurrence of antigens B2, I1, Y2, E'3, F',O', C1, R2, J, S1, U", and a decrease of O4, X2, L'. At the same time, the antigens A1, A2, D', Q', W, V, H"', and Z are constant. It can be stated that in 10 years there have been changes in the gene pool of breeding farms of the republic. This indicates the influence of directed selection, and the change in the concentration of antigens is explained by the more intensive use of individual male producers. Monitoring in the republic reflects only empirical data and does not include the influence of individual factors on the change in the gene pool.

The characteristic of the genetic structure of different breeds by blood antigenic factors has shown that the polymorphism of erythrocyte antigens is quite diverse. The highest frequency of occurrence of Kalmyk breed antigens in the Republic of Kalmykia: A1 ,A2, B2, O2, E'3, C1, W, Z, the lowest: B', C2. Antigens A1, I', C1, W, L, F were found with the maximum frequency in the Kazakh white-headed breed, with the lowest B2, G3, Y2, F', C2, X2, U". The Hereford breed has the highest frequency of G2, O3, Y2, Q, C2, X2, L, V antigens, the lowest: B2, I1, I', R2. The Simmental breed had a maximum value of A2, Y2, C1, C2, H", with a minimum value of G3, I1, F', X2, S1. A1, A2, E'3, R2, L, F, and Z had antigens of the Kalmyk breed in the Astrakhan region with the highest frequency. Antigens with the lowest frequency G3, I1, A'2, O4, Y2, B', F', C2. Antigens with the highest frequency were detected in both Kalmyk cattle of the republic and the Astrakhan region — A1, A2, E'3, O', Z. Based on the data, it is possible to assume the typicality of these antigens of this breed and the genetic marking of Kalmyk cattle purebred.

The identification of the most effective method of selection, taking into account the index of genetic similarity, revealed the smallest number of parent pairs in the low (0.0-0.30) and high (0.61-0.90) indices of antigenic similarity and amounted to: "Agrofirma Aduchi" LLC - 24 pairs (16%) and 48 pairs (32%), "Sarpa" AO - 17 pairs (11%) and 21 pairs (14 A. Chapchayev AO PZ – 15 pairs (10%) and 9 pairs (6%), "Agribusiness" LLC - 8 pairs (5%) and 7 pairs (5%), respectively. When selecting parent pairs with an antigenic similarity index of 0.31-0.60, it allows getting bulls with the highest live weight. Of the indicators characterising the difference between bullheads having a different index of genetic similarity, preference should be given by live weight at the age of 15 months, since the main implementation is by live weight at this age. The difference in the live weight of bullheads at 15 months of age with an index of 0.31-0.60 is reliable and can serve as a selection criterion. For the reproduction of cattle of the Kalmyk breed, the selection of parental pairs with an index of antigenic similarity not exceeding 0.31–0.60 is carried out.

Antigens A1, A2, G2, E'3, C2, Z are genetic markers of the reproductive ability of Kalmyk cattle.

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References

1. S. Allais et al., Journal of Animal Science **89**, 1-11 (2011)
2. A. V. et al., Rozvedennya i Henetyka Tvaryn **49**, 154-163 (2015)
3. C. A. Bonilla et al., Genetics and Molecular Research **9(4)**, 2395-2405 (2010)
4. A. Hadef et al., Annals of Biological Research **5(9)**, 31-37 (2014)
5. O. B. Gendzhieva et al., Proceedings of the III international research and practice conference. Westwood, Canada, **2**, 20-25 (2013) ISBN 978-1-77192-013-1
6. I. F. Gorlov et al., Rendiconti Lincei **29(1)**, 61-66 (2018)
7. T. D. Carvalho et al., Revista Brasileira de Zootecnia **10**, 2162-2168 (2012)
8. L. G. Moiseykina et al., Modern Journal of Language Teaching Methods, Revista Publicando, Ecuador 8(12), 621-628 (2018) ISSN:2251-6204
9. N. T. Onkorova et al., Proceedings of the 23rd Annual Conference of the European Society for Domestic AnimalReproduction (ESDAR), St Petersburg, September 2019 (2019)
10. E. O. Unal et al., Turk J Zool **39**, 1 – 15 (2015)
11. H. Yardibi et al., African Journal of Biotechnology **12(20)**, 2802-2807
12. N. V. Shirokova et al., IOP Conference Series: Earth and Environmental Science 677, 52-56 (2021)
13. L. Skorykh et al., Research Journal of Pharmaceutical, Biological and Chemical Sciences **8(6)**, 529-534 (2017)
14. F. R. P. Souza et al., J. Anim. Scie. **88**, 435-441 (2010)
15. J. Xia et al., Mammalian Genome **27 (5-6)**, 246-255 (2016)