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Heterozygosity as a factor of increasing the meat productivity of kalmyk steers

[*Heterozigosidade como fator de aumento da produtividade da carne de bois kalmyk*]

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ABSTRACT

The present work carried out full-genome SNP genotyping of 16-month-old Kalmyk steers to study their productive characteristics and beef quality indicators in the leading farms of the Republic of Kalmykia (Group I was located at the Agrofirma Aduchi farm; Group II at the Kirovsky breeding plant, and Group III at the Plodovitoye agricultural cooperative). As a result of investigating the frequencies of some homozygous alleles, the study established that the heterozygous allele A/A varied considerably along the lines from 0.2785 to 0.3146, while B/B varied from 0.3697 to 0.4125. Meanwhile, the heterozygous allele A/B varied from 0.2986 to 0.3197. Estimated inbreeding coefficients were 1.35, 1.28 and 1.27%. The conducted studies established a higher natural resistance determined by lysozyme, bactericidal and phagocytic activities of steers raised at the Agrofirma Aduchi as farm than their counterparts at the other agricultural enterprises. Over the entire period of the experiment, the steers from 8 to 16 months of age in Group I exceeded the indices of their counterparts in Groups II and III by 30.46g, or 3.31% and 38.04g, or 4.16%, respectively. It is concluded that an increase in the heterozygosity of the studied Kalmyk steers not only results in higher meat productivity, but also improves the quality of carcass and beef quality, increases the yield of more valuable meat grades, and optimizes the fractional composition of proteins.

Keywords: steers, genotyping, immunoglobulins, live weight, meat

RESUMO

O presente trabalho realizou a genotipagem de bois Kalmyk de 16 meses de idade para estudar suas características produtivas e indicadores de qualidade da carne bovina nas principais fazendas da República de Kalmykia (o Grupo I estava localizado na fazenda Agrofirma Aduchi; Grupo II - na planta de criação Kirovsky; Grupo III - na cooperativa agrícola Plodovitoye). Como resultado da investigação das freqüências de alguns alelos homozigotos, o estudo estabeleceu que o alelo heterozigotos A/A variou consideravelmente de 0,2785 a 0,3146, enquanto o B/B variou de 0,3697 a 0,4125. Enquanto isso, o alelo heterozigoto A/B variou de 0,2986 a 0,3197. Os coeficientes estimados de consanguinidade foram de 1,35, 1,28 e 1,27%. Os estudos realizados estabeleceram uma maior resistência natural determinada pelas atividades lisozóides, bactericidas e fagocitárias dos bois criados na Agrofirma Aduchi como fazenda do que suas contrapartes nas outras empresas agrícolas. Durante todo o período do experimento, os bois de 8 a 16 meses de idade no Grupo I excederam os índices de suas contrapartes nos Grupos II e III em 30,46g, ou 3,31% e 38,04g, ou 4,16%, respectivamente. Conclui-se que um aumento na heterozigosidade dos bois Kalmyk estudados não só resulta em maior produtividade da carne, mas também melhora a qualidade da carcaça e da carne bovina, aumenta o rendimento das carnes de maior valor e otimiza a composição fracionária das proteínas.

Palavras-chave: novilhos, genotipagem, imunoglobulinas, peso vivo, carne

INTRODUCTION

In the Russian livestock industry, where intensive cattle breeding approaches are confined to a particular farm at which measures are undertaken for improving certain economic traits, a situation has arisen in which the consolidation of individual animals closely related to their ancestors results in considerably reduced livestock biodiversity [Ajmone *et al.*, 2010; Caballero *et al.*, 1996; Calabrese *et al.*,

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2011]. Currently, various indigenous cattle breeds are raised in Russia, including the Kalmyk breed, which is undergoing constant improvement [Ajmone *et al*., 2010].

As well as presenting outstanding adaptability to almost any climatic conditions, Kalmyk steers have a high genetic potential for meat productivity. Additionally, beef from fattened Kalmyk steers is known to have unique gustatory qualities [Ajmone *et al*., 2010; Carolino *et al*., 2008; Cherepanov *et al*., 2012]. For this reason, cattle of this breed are widespread throughout the territory of the Russian Federation. Kalmyk cattle are raised on the territories of the Southern Urals (Orenburg Oblast and Bashkortostan), Western and Eastern Siberia (Trans-Baikal and Primorsky regions, Omsk Oblast and the republics of Buryatia, Tuva, and Yakutia), the North Caucasus (Rostov Oblast, Stavropol Krai, Ossetia and Chechnya), Lower Volga region (Republic of Kalmykia, Volgograd and Astrakhan Oblasts), Samara, Tver and Ryazan Oblasts, as well as the Primorsky Krai [Chernomyrdin *et al*., 2014; Dorado *et al*., 2017; Eremenko *et al*., 2011; Gilbert *et al*., 1988].

A priority research direction In the selection and breeding of Kalmyk cattle aims at improving methodological approaches to the development of genomic analysis technologies for identifying gene pool features of cattle bred in different farms. The obtained knowledge will enable more the efficient development of beef cattle that are adapted to specific environmental conditions [Dorado *et al*., 2017; Eremenko *et al*., 2011; Gilbert *et al*., 1988; Houston *et al*., 2004]. In this regard, the possibility of increasing production of high-quality beef due to improved understanding of the biological characteristics of Kalmyk cattle based on modern genetic research methods is of great theoretical and practical importance.

The present study conducted full-genome SNP genotyping in order to study the productive characteristics of 16-month-old Kalmyk steers along with beef quality indicators in the leading farms of the Republic of Kalmykia – i.e., Agrofirma Aduchi LLC, Kirovsky stud farm JSC and the Plodovitoye agricultural production cooperative.

MATERIALS AND METHODS

For the purposes of conducting an experiment on the abovementioned farms, 3 groups of 8-month-old steers were formed, i.e., Groups I, II and III, comprising 30 head each. Each group was kept under similar conditions concomitant with accepted beef cattle breeding norms. For the experiment, we selected steers of the following genealogical lines: Moryak 12054, Zimmer 7333 and Report 1279 at the Agrofirma Aduchi farm; Borovik 7273, Strojnyj 2520 and Rezvyj 2024 at the Kirovsky stud farm; and Manezh 7113, Block 3218 and Jaguar 253 at the Plodovitoye cooperative. Each line was represented by 10 head of individual cattle.

The steers were fed diets developed according to the Kalashnikov recommendations using the Hybrimin®Futter5 program (Germany) aimed at obtaining average daily gains of 850–1000g. As well as grazing on the year-round pasture, the steers were fed with compound feed in the evening (3–4kg per head).

For laboratory studies, we selected 5 carcasses of Kalmyk steers grown in farms mentioned above. The controlled slaughter of 16-month-old steers was carried out according to the accepted technological norms (GOST R 54315-2011). Sampling of raw meat and fat was performed following a 24-hour exposure. During the experiment, animals were treated and kept in accordance with instructions and recommendations of the applicable Russian regulations 1987 (USSR Ministry of Health Order No. 755 on 12.08.1977) and The Guide for Care and Use of Laboratory Animals (National Academy Press Washington, DC 1996). Appropriate measures were taken to prevent or minimize animal suffering and use the least possible number of samples.

In the selected experimental meat samples, the moisture content was determined by drying the sample to a constant weight. Fat was established by extracting a dry weighed sample in a Soxhlet apparatus, while protein was determined according to the nitrogen content in Kjeldahl flasks using isometric distillation in a Conway dish. The protein quality index was calculated as a ratio of tryptophan determined by the Neumann-Logan method (based on the condensation of mineral acid vapor in a

dimethylbenzaldehyde solution, which were then stained blue with sodium nitrite) to oxyproline obtained using the Spies-Chambers method (based on determining the content of oxyproline in collagen, which is oxidized and determined by a color reaction following hydrolysis of muscle tissue).

The laboratory studies were performed at the Federal Research Center for Animal Husbandry n.a. Academy Member L.K. Ernst at the Laboratory of Functional and Evolutionary Genomics of Animals, Animal Biotechnology Scientific Infrastructure Object, and the Center for Farm Animal Bioresources and Bioengineering.

The DNA was extracted using a DNA Extran 2 reagent kit (ZAO Syntol, Moscow, Russia). The qualitative DNA assessment was conducted based on the data obtained from a NanoDrop 8000 microspectrophotometer (TermoFisher, USA), while the double-stranded DNA concentration was quantified using a Qubit instrument (TermoFisher, USA). The purity of the separated DNA sections was determined as a ratio of the absorption value at a wavelength from 260 to 280nm.

Using the PLINK 1.9 software package for the Bovine HD BeadChip high-density DNA chip (Illumina Inc., USA), whole genome genotyping was performed with a set of approximately 777 thousand single nucleotide polymorphisms (SNPs) comprising certain sequences of a DNA region. The obtained data were filtered with respect to the following indicators: Call-rate per SNP over samples repeated of at least 90% (--mind); similarly for genotyped samples (--geno); the minor allele frequency (MAF) of more than 0.01 or 0.05 (--maf 0.01); and deviation from the Hardy-Weinberg equilibrium in the studied samples with a p-value<10-6 significance level (--hwe). The estimated linkage disequilibrium (LD score) of the studied SNPs (r2<0.2) was measured at a step of 50 kb (--indep-pairwaise).

Population-genetic indicators, i.e., heterozygosity (H_o) (unmixed, expected), allelic diversity (Ar) and inbreeding coefficient at a 95% confidence interval (Fis), were calculated in the diversity software package (group R) using the selected SNP genotypes [Huang and Wang, 2013; Kayumov and Chevkhuzhev, 2016; Kayumov and Chevkhuzhev, 2016].

The quantity of immunoglobulins of individual classes (isotypes) was calculated twice by the Mancini method of radial immunodiffusion, distributing monospecific antiserum and monoclonal antibodies to certain classes of immunoglobulins and the reference standard blood serum of steers to the control content of immunoglobulins of individual classes [Keenan *et al*., 2013; Kim *et al*., 2000].

All materials obtained in the experiment were processed by statistical methods of variation, using the Excel program (Microsoft, USA); the significance was determined in the Statistica 10.0 program (Stat Soft Inc., USA).

RESULTS

Isolation of DNA from the blood samples showed that the individual biomaterial of the Kalmyk cattle has the following qualitative and quantitative indices (Table 1).

Table 1. Quantitative and qualitative DNA indices of cattle of the Kalmyk breed (P>0.999)

No	Number of samples	ID ViZh	Qubit, ng/µl	OD260/ OD280
1	30	aduchi CKP BOS 217	53.7	1.853
2	30	kirovskij CKP BOS 201	43.8	1.838
3	30	plodovitoye CKP BOS 218	43.6	1.829

The obtained data on the studied samples presented in Table 2 show that the steers at the Agrofirma Aduchi farm outperformed the steers at the Kirovsky and Plodovitoye locations in terms of the double-stranded DNA concentration, with the biomaterial of the former containing an average of 53.7ng/µl, which was significantly higher by 9.9ng/µl, or 18.44% and 10.1ng/µl, or 18.81%. However, it should be noted that the average frequency of individual DNA segments, which ranged from 1.83 to 1.85 OD260/OD280, did not differ.

Table 2. The content of immunoglobulins in the blood serum of Kalmyk steers, mg/mL

Immunoglobulin	Group		
	I	II	III
LgG	24.12±0.12	22.87±0.09**	23.21±0.11**
LgM	2.84±0.04	2.76±0.03	2.69±0.05*
LgA	0.89±0.02	0.67±0.03**	0.64±0.05**

The genotyping of steers to certain lines established that all the studied steers had an average value of 0.997%, which was a fairly high level of belonging to the lines.

The study of the frequency of individual homozygous alleles gave the following results: A/A varied significantly along the lines from 0.2785 to 0.3146; B/B varied from 0.3697 to 0.4125; while the heterozygous allele A/B varied from 0.2986 to 0.3197.

The estimated inbreeding coefficients were 1.35, 1.28 and 1.27% for the Moryak 12054, Zimmer 7333 and Report 1279 lines, respectively; they were lower by 0.12, 0.06 and 0.13% in comparison with the Borovik 7273, Strojnyj 2520 and Rezvyj 2024 lines, and by 0.09, 0.21 and 0.18% compared with the Manezh 7113, Block 3218 and Jaguar 253 lines, respectively.

The obtained results indicated a higher degree of inbreeding (moderate) in animals in the Kirovskiy stud farm and Plodovitoye cooperative compared with the Agrofirma Aduchi farm, confirming the suggestion that they had a significantly lower rotation of livestock and possibly related or closely related inappropriate mating of animals.

Due to the high frequency of closely related mating of Kalmyk cattle occurring in the Republic of Kalmykia, we studied the effect of inbreeding in the Plink 1.9. program, with available genotypes being pre-processed in terms of the minor allele frequency (MAF) – namely, the Handy-Weinberg equation with the confidence defined and the IBS method. The latter (identity by state) was used to construct multidimensional scaling (MDS) graphs that reflected the animals from different analyzed populations that were similar by descent (Figure 1).

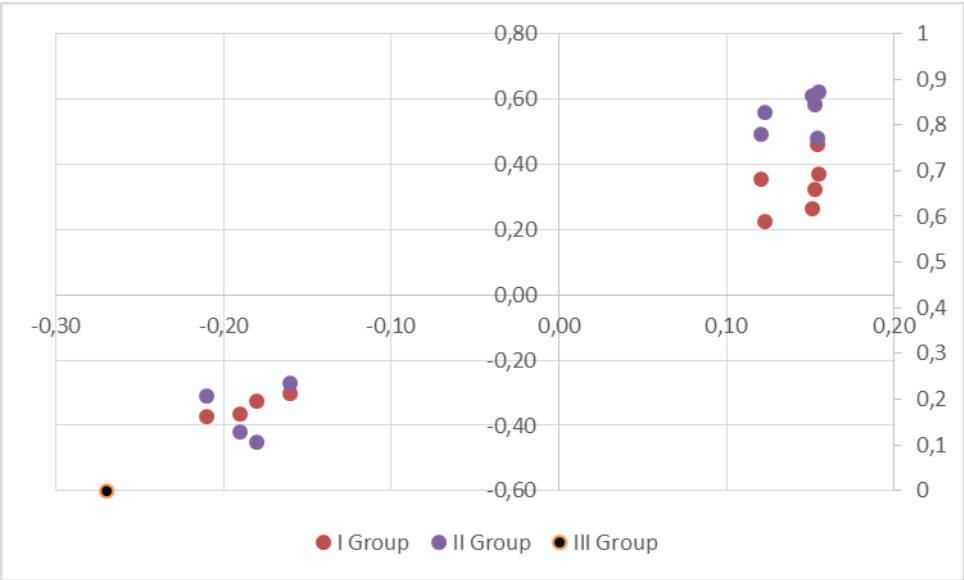


Figure 1. The origin of animals in different farms: steers of the Moryak 12054 line are highlighted in red; Strojnyj 2520 line's counterparts are blue; and Jaguar 253's line is black.

As follows from Figure 1, all the genealogical groups of animals raised in the studied farms were divided into isolated dense groups. When comparing other lines, similar graphic images were obtained. The separation of animals in lines turns out to be an effective tool for identifying new combinations of intra-line selection and desirable line crosses. The unique allele pool combination represented by the studied lines of Kalmyk cattle allows them to be considered as a reserve for more efficient use in beef cattle breeding.

To assess the productive properties of cattle, a scientific and economic experiment was carried out. The analysis of spring-summer pasture forage available at the considered farms in the Republic of Kalmykia identified the following plants: kochia prostrata, eurotia, poa bulbosa, agropyron elongatum, thinopyrum intermedium, poterium, astragalus, trigonetla and isatis. In the plowable (year-round) pastures at different periods of the year, eurotia, camphorosma, kochia prostrata, artemisia halophila, distichlis, agropyron elongatum, leymus junceus, thinopyrum intermedium, poterium, astragalus sphaerocephalus, agropyron desertorum and agropyron cristatum were shown to be present. During the period of heavy snowfall, animals were fed with mixed grass hay stored in advance. All the farms participating in the experiment had similar feeding conditions.

To establish physiological states of the experimental animals, we studied their hematological factors. In terms of erythrocyte content, the steers in Group I exceeded their counterparts in Groups II and III by 8.76 (*p>0.99*) and 5.23% (*p>0.95*); with respect to leukocytes – by 0.48 and 0.26%; in terms of hemoglobin – by 1.65 and 0.98%, respectively. Since these higher values of hematological factors in Group I did exceed physiological norms, they served as indirect evidence of increased metabolic processes in the body – and hence the high productivity of the steers.

The study of the natural resistance of the body showed that the steers in Group I surpassed their counterparts in Groups II and III in terms of lysozyme, bactericidal and phagocytic activities by 1.24% (*p>0.95*) and 0.86%; by 2.12% (*p>0.95*) and 1.76% (*p>0.95*); and by 1.42% (*p>0.99*) and 1.18% (*p>0.95*), respectively.

The study of immunoglobulins in the blood serum of the experimental steers is presented in Table 2.

Table 2 shows that the Group I steers were superior to the steers in Groups II and III in terms of all studied parameters: in terms of the LgG immunoglobulin content by 1.25mg/ml, or 5.18% (*p>0.99*) and 0.91mg/ml, or 3.77% (*p>0.99*); by 0.08mg/ml, or 2.82% and 0.15 mg/ml, or 5.28% (*p>0.95*) with respect to Lg M immunoglobulins; and by 0.22mg/ml, or 24.72% (*p>0.99*) and 0.25mg/ml, or 28.09% (*p>0.99*) in terms of LgA immunoglobulins, respectively. Thus, steers grown in the Agrofirma Aduchi farm were superior with respect to all three immunoglobulin types.

Higher values of hematological and immunobiological status of steers in Group I affected their productive capacity (Table 3).

Table 3. Dynamics of the live weight and the growth intensity of experimental steers, kg(n=30)

Age, months	Group		
	I	II	III
8	232.24±1.44	231.60±1.22	231.70±1.27
10	266.40±2.15	260.48±1.76*	259.35±1.64*
12	327.63±2.56	320.86±1.67*	319.69±1.73*
14	398.36±1.89	392.74±1.83*	391.66±1.68*
16	454.23±1.96	446.28±2.15*	444.56±1.93**

The calculated overall live weight gains showed that Group I steers exceeded their counterparts in Groups II and III by 5.28kg, or 15.46% (*p>0.999*) and 6.51kg, or 19. 06% (*p>0.999*) in the age period from 8 to 10 months; by 0.85kg, or 1.39% (*p>0.99*) and 0.89kg, or 1.45% (*p>0.99*) in the age period from 10 to 12 months; by 1.15 kg, or 1.63% (*p > 0.999*) and 1.24kg, or

1.75% (*p>0.999*) in the age period from 12 to 14 months; and by 2.33kg, or 4.17% (*p>0.999*) and 2.97kg, or 5.32% (*p>0.999*) in the age period from 14 to 16 months, respectively. Over the entire period of the experiment, the steers in Group I exceeded their counterparts in Groups II and III by 7.31kg, or 3.29% (*p>0.999*) and 9.13kg, or 4.11% (*p>0.999*) in terms of the overall gain.

Similar dynamics were confirmed by the values of the overall daily live weight gain. Over the entire period of the experiment involving young cattle aged from 8 to 16 months, the steers in Group I exceeded their counterparts in Groups II and III by 30.46 g, or 3.31% (*p>0.999*) and 38.04 g, or 4.16% (*p>0.999*), respectively.

However, the most unbiased data on the productive capacity of the steers under study were provided by the control slaughter of 5 head from each group, which provided the following results: carcass yield parameter – 59.6, 54.86 and 55.63%; slaughter yield parameter – 57.9, 57.4 and 58.4%, respectively.

Grade cutting of the experimental carcass meat showed that the carcasses of steers in Group I comprised more meat than those in Groups II and III by 5.78 kg, or 2.43% (*p>0.95*) and 7.45kg, or 3.13% (P>0.959); top-grade meat by 3.65 kg or 10.83% (*p>0.999*) and 2.44 kg or 7.23% (*p>0.99*); and grade I meat by 6.17kg, or 4.72% (*p>0.99*) and 6.03kg, or 4.61% (*p>0.95*), respectively. Thus, the yield of top-grade meat was higher by 1.22 and 0.60% and the yield of grade I meat by 1.29 and 0.84%. However, steers in Groups II and III surpassed their Group I counterparts by 4.05kg, or 5.22% (*p>0.99*) and 1.02kg, or 1.37% in terms of the weight of grade II meat; and by 2.51 and 1.44% with respect to the yield of grade II meat (Table 4).

Table 4. Meat grading of carcasses of experimental Kalmyk steers (n=5)

Parameter	Group		
	I	II	III
Meat weight, kg	238.24±1.34	232.46±1.26*	230.79±1.28**
Weight of top-grade meat, kg	33.73±0.33	30.08±0.29***	31.30±0.31**
Yield of meat, top grade, %	14.16	12.94	13.56
Weight of meat, grade I, kg	130.94±0.86	124.76±0.79**	124.90±0.84*
Yield of meat, grade I, %	54.96	53.67	54.12
Weight of meat, grade II, kg	73.57±0.66	77.62±0.59**	74.59±0.57
Yield of meat, grade II, %	30.88	33.39	32.32

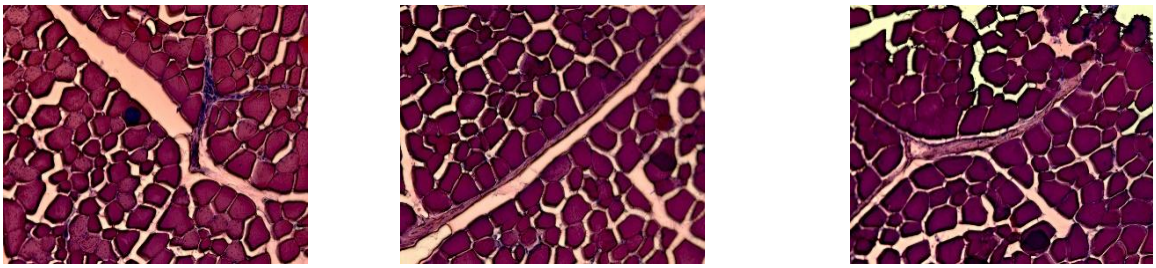
The chemical composition of the longissimus dorsi muscle is of great importance in assessing the carcass quality; due to this muscle being the largest in the carcass, its quality indicates the overall assessment [Ajmone *et al*., 2010; Chernomyrdin and Kaymov, 2014; Dorado, *et al*., 2017; Klobasa and Butler, 1987] (Table 5).

Table 5. Chemical composition of longissimus dorsi muscle of Kalmyk steers (n=5)

Parameter	Group		
	I	II	III
Moisture, %	75.63±0.32	75.88±0.35	76.03±0.37
Dry matter, %	24.37±0.22	24.12±0.23	23.97±0.24
Protein, %	21.18±0.18	20.98±0.16	20.75±0.19
Fat, %	2.34±0.06	2.3±0.05	2.24±0.07
Ash, %	0.85±0.08	0.84±0.06	0.98±0.07
Tryptophan, mg	423.75±0.48	435.14±0.52	430.56±0.43
Oxyproline, mg	58.67±0.35	61.23±0.29	61.23±0.33
Protein quality indicator PQI, mg	7.22	7.11	7.03

The data on the chemical composition of longissimus dorsi muscle presented in Table 6 show that the steers in Group I exceeded their counterparts in Groups II and III by 0.25 and 0.40% in terms of dry matter content; by 0.20 and 0.43% in terms of protein content; and by 0.04 and 0.10% in terms of fat content, respectively. While the meat from steers in Group I was inferior to the meat in Groups II and III by 11.39mg, or 2.62% ($p>0.999$) and 6.81 mg, or 1.58% ($p>0.999$) in terms of the tryptophan content and by 2.56mg or 4.18% ($p>0.99$) and 2.56mg or 4.18% ($p>0.99$) in terms of the hydroxyproline content, in terms of protein quality, the meat from steers in Group I exceeded the meat in Groups II and III by 0.12mg, or 1.60% and 0.19mg, or 2.64%, respectively.

The steers in Groups II and III had better indices with respect to other parameters under study. One of the most important parameters characterizing the quality of beef, especially from beef cattle, is "marbling". The assessment of the microstructure of the *longissimus dorsi* muscle carried out as part of our studies is as depicted in Figure 2.



a) b) c)

Figure 2. Microstructure of the longissimus dorsi muscle of Kalmyk steers of different lines: a) is the Moryak 12054 line; b) is the counterparts of the Slender 2520 line; and c) is the counterparts of the Jaguar 253 line

Analysis of the obtained results on the microstructure of the *longissimus dorsi* muscle demonstrate a fairly clear pattern characterizing the beef from all experimental steers, including clearly distinguished muscle and fat fiber boundaries, as well as visible lipid inclusions. However, the steers raised on the Agrofirma Aduchi farm had a more clearly visible picture of *longissimus dorsi* muscle. This may be due to their gene pool determining higher live weights and beef quality indices.

Assessing the quality of beef from experimental steers involved the fractional composition of meat proteins. The biological value (BV) of meat is directly dependent on its full value associated with the proportional ratio of its fractions, namely: sarcoplasmic (most complete), myofibrillar (complete) and stroma (least complete) (Table 6).

Table 6. Fractional composition of beef proteins, %

Parameter	Group		
	I	II	III
Total protein, incl.	21.18±0.24	20.98±0.22	20.75±0.25
sarcoplasmic	4.93±0.03	4.62±0.02**	4.57±0.04**
myofibrillar	8.43±0.05	8.56±0.04	8.50±0.06
stroma	7.82±0.06	7.80±0.05	7.68±0.04
Protein Completeness Ratio (PCR)	1.71	1.69	1.70

DISCUSSION

Many recent scientific works have been devoted to the study of molecular, genetic, and productive characteristics of cattle and other farm animals (Liu *et al*., 2012; Huang and Wang, 2013; Song *et al*., 2012; Kim *et al*., 2000, 2004; Houston *et al*., 2004; Stachowiak *et al*., 2005; Loftus *et al*., 1994, 1994; Manchini *et al*., 1965).

The reduction or even elimination of mating siblings in a reproduction system has been established to be an important condition for reducing inbreeding rates and the deviation from Hardy-Weinberg proportion on the population (Caballero *et al*. 1996; Notter, 1999; Polovinko *et al*., 2016; Pristupa *et al*., 2020).

Although some researchers believe that inbreeding adversely affects the safety and live weight of calves, it has been shown that inbreeding depression does not affect the meat qualities of carcasses (Carolino and Gama, 2008; Santana *et al*., 2010; Ugnivenko, 2018). The high relevance of inbreeding depression was noted by Dorado *et al*. (2017) who demonstrated its effect on the sperm quality and fertility of beef bulls. It has been found that calves with high inbreeding percentage of sire within the line and serum LgG of less than 10 mg/ml were more likely to die before weaning. The heritability estimates of LgG were measured as a trait of the dam (Gilbert *et al*., 1988; Santana *et al*., 2010; Smith, 2016; Stachowiak *et al*., 2005; Surundaeva *et al*., 2018; Vovchenko *et al*., 2019; Wu *et al*., 2015; Yang *et al*., 2013; Zinovieva *et al*., 2016).

The level of natural resistance of the animal organism is associated not only with health or viability, but also with stress resistance and adaptive capabilities (Calabrese *et al*., 2010, 2011; Cherepanov and Bogdanova, 2012). The metabolism, nonspecific resistance of the organism (Eremenko and Sein, 2011) and the ratio of fatty acids in marbled meat (Wu *et al*., 2015; Smith, 2016) are known to depend on the genetic characteristics of the livestock.

The research presented in the present article is aimed at revealing new data about the influence of genetic factors on the productive and qualitative properties of meat breeds and deepening knowledge on the economic and biological characteristics of Kalmyk cattle, one of the oldest aboriginal Russian breeds. Features of marbled meat from 16-month-old Kalmyk steers obtained from the leading farms of the Republic of Kalmykia are discussed in detail. The presented results of experimental studies are of great importance for the development of world animal husbandry and providing the human planetary population with high-quality marbled beef.

CONCLUSIONS

The results of the study support the inference that the high genetic diversity of the studied Kalmyk cattle has developed due to the natural mating of animals in a herd rearing system operated in the Republic of Kalmykia, in which territory this breed has a rather large population. An increase in the heterozygosity of Kalmyk cattle at the Agrofirma Aduchi farm improved their meat productivity, carcass quality, yield of more valuable meat grades and quality, as well as optimizing the fractional protein composition.

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