AGRICULTURAL BIOLOGY,
2018, V. 53, № 2, pp. 309-317
(SEL'SKOKHOZYAISTVENNAYA BIOLOGIYA)

ISSN 2412-0324 (English ed. Online)
ISSN 0131-6397 (Russian ed. Print)
ISSN 2313-4836 (Russian ed. Online)

UDC 636.2:636.082:591.111.1:616-097

doi: 10.15389/agrobiology.2018.2.309eng
doi: 10.15389/agrobiology.2018.2.309rus

THE ASSOCIATION BETWEEN BLOOD GROUP AND REPRODUCTIVE PERFORMANCE IN CATTLE

O.S. SHATALINA

Ural Research Institute of Agriculture, Federal Agency of Scientific Organizations, 21, ul. Glavnaya, pos. Istok, Ekaterinburg, 620061 Russia, e-mail shatalinao@list.ru (✉ corresponding author)
ORCID: Shatalina O.S. orcid.org/0000-0002-9796-7677
The author declares no conflict of interests
Received May 13, 2016

Abstract

Modern development of animal breeding is impossible without the implementation of molecular genetic methods, the use of which allows searching for reliable biomarkers of the desired development of economically useful traits in farm animals based on the analysis of hereditary information. Thus, immunogenetic methods allowed significant reduction of errors in the control of pedigree of breeders. Studies of the interrelationships of blood groups with economically useful signs of animals are in progress. Infertility and barrenness in cattle lead to huge economic losses. The purpose of this work was to identify the relationship between antigenic similarity of blood groups in parents and reproduction indicators in cattle. The study was carried out from 2009 to 2014 in Sverdlovsk Region in the livestock farms Mezenskoe LLC (Beloyarsky Region), Pervouralsky Integrated Agricultural Production Center (Pervouralsk Town District) and Artemovsky Farming Company LLC (Artemovsky Region) using 1300 pairs of Ural-type black-and-white cattle. The mated animals were authentic in origin and certified for blood groups. For their certification, 54 monospecific sera to 11 blood group systems were used. In mated animals the index of antigenic similarity of blood groups, expressed as the ratio of similar antigens in bulls and cows to their total number, and homozygosity on EAA, EAF, and EAZ blood group systems were calculated. These blood group systems were represented by several antigens which makes it possible to trace immune conflict in mated animals. By biometrical processing, it was identified that the pairs which were heterozygous in EAA and EAF antigens showed higher efficiency of conception and better survival of the offspring, though the twinning frequency decreased. The parents homozygous in EAA system produced the progeny in which the amount of aborted embryos was 2.5 % higher than that in the heterozygous pairs. The number of calves born dead from the EAF-homozygous pairs was twice as much as that of heterozygous pairs. Apparently, the immune conflict, which leads to the extended period from delivery to productive insemination and higher offspring death, decreases in animals homozygous in EAZ system. The number of calves born dead was 3.2 % for homozygous pairs and 4.7 % for heterozygous pairs. The index of antigenic similarity of parents varied from 0.1 to 0.8. If the antigenic similarity of the mated animals was 10 %, significant losses of calves were observed. If the antigenic similarity was 20 %, such losses increased but not significantly. The similar patterns were observed for the twinning. If the index of antigenic similarity of the mated animals was from 0 to 0.1, the maximum twins were born, and if the index of similarity was 0.2 or more, the number of twins increased, but gradually. Thus, the antigenic similarity of mated animals influences the number and survival of born calves.

Keywords: cattle, antigens, blood groups, index of antigenic similarity, homozygosity, multiple fetus, survival of calves

The most acute problem in modern cattle breeding industry is improvement of reproduction indicators in cattle at preservation of high milk yields. One of ways to improve reproduction indicators is search of relationships between the antigen alleles and blood groups and economically useful traits. Determination of blood groups (protein antigens of erythrocyte plasma membrane) in cattle is widely used for validity check of origin, studying of the gene pool of cattle populations, studying of relations between the blood groups and economically useful traits, and selection of pairs by antigen similarity [1, 2]. Identification of genes polymorphism of which is associated with variability in performance of economically useful traits became possible due to progress of molecular genetics and molecular biology [3, 4]. Studies and comparative analysis of blood groups are important for studying the evolution of agricultural animal breeds [5]. These studies enable revising the breed formation processes and forecasting of heterotic effects in crossbred animals [6].

One of reproduction indicators is fertility as an evolutional ability of each kind to give birth in natural conditions, thus, compensating death rates. Multiple pregnancies are an important reproduction indicator in animals which depends on fertility [7]. The bigger the animal, the longer its life span is, and the longer is the embryonic development, the lesser is multiple pregnancies' rates. Cattle refers to oligocarpous category, whereupon the effectiveness of reproduction in cattle acquires an important economic value [8]. Growth of milk yields in cows is often accompanied by decrease of its adaptive potential and decrease of reproduction effectiveness [9]. Moreover, animal genotypes have a great effect on reproduction indicators [10]. Spontaneous mutations occurring in the seed bulls may be widely spread across the breed in cattle of highly-specialized milk breeds, such as Holstein, which are under the intensive pressure of artificial selection [11-13]. In particular, such mutations include BLAD (bovine leukocyte adhesion deficiency associated with death in calves aged under 1 year) and CVM (complex vertebral malformation) [14]. Reproduction indicators in cattle are not only influenced by physiological but also anthropogenic factors [15]. Thus, infertility and dry stat of cows are negative consequences of improperly performed insemination [16].

Infertility in both sexes is a loss of animal ability to reproduce because of a dysfunction in mature organism. Temporary (reversal) and persistent (irreversal) infertility is distinguished in cows [17]. At that, genetic infertility happens quiet rarely since from the biological point of view there are no animals with genetically limited reproduction indicators [18, 19]. Annually, each infertile cow produces less milk products (nearly 3 kg of milk per each day of infertility). Signs of infertility in cows and young cows are manifested in longstanding lack of estrum, availability of infertile inseminations [20]. Usually, 17-23 % of animals are involved in estrum during the month 1, 48-55 % during month 2, and 18-22 % during month 3 after calving. Interval from calving to the first estrum is 2 months. Therefore, each cow failing to be fertilized during 60 days after calving should be deemed infertile.

Effective prevention of infertility and dryness are important to increase cattle livestock, milking capacity, and to optimize reproduction [20, 21]. Dryness is an economic parameter applied to cattle females only [22, 23]. Dryness is mainly caused by innate infertility, false identification of estrum and untimely insemination, lack of motion, low quality of feed, infringement of insemination technology, and use of pure quality sperm. Infertility and dryness may be also caused by infection diseases [24, 25] and genetically determined disorders of reproductive health [26]. High yieldness in stud stock results in production of less milk, calves, and causes significant economic damage. In breeding farms allowing for 10 % infertility in cows at milk yield of 2500-3000 kg, milk yield is reduced by 5 % and consumption of feed per unit of produced milk increases. Increased duration of infertility in cows by 1 day decreases the annual milk in cows by 6 kg. For preservation of the high calving it is required to optimize the insemination terms and animal selection for mating [27], to use vitamin and mineral additives improving the reproduction indicators [28].

At embryo formation in humans, antigens of mother and father blood groups affect the immunologic balance [29, 30]. Similar tests were conducted in animals. It was noted that several loci and blood group antigens in cattle also affect fertilization and gestation courses [31]. S.L. Gridina et al. [32] had established that fertilization in cows depends on antigen combination. Fertility is increased at absence of J antigen, homozygosity of parents by antigens Y_2 and G_2, and heterozygosity by antigens A_2 and S_2. Presence of A_1, B_2, G_3, I_2, O_2, $A^I{}_2$, G^I, R_2, W, X_2, and S antigens in blood of bulls and absence thereof in cows promotes growth of fruitful insemination frequency. S.L. Gridina et al. [33] and V.F. Gridin et al. [34] had found alleles (cohesively inherited antigens) of cattle blood groups controlling the economically useful traits. Studies of I.M. Starodumov et al. [35] and L.V. Kerro [36] had shown that blood groups may be used for selection and breeding, as well as for improvement of economically useful traits in cattle.

The present paper for the first time shows correlation between the antigen similarities in cattle pairs of Ural breed and reproduction properties, and also indicates that the animal blood groups are unequally associated with different traits.

Purpose of our paper is studying the relationship between the inheritance of blood antigens and reproductive indicators in groups of Ural Holstein Black Pied cattle.

Techniques. Study was conducted from 2009 to 2014 in Sverdlov Region in Mezenskoye LLC (Beloyarskiy Region), Agricultural Breeding Cooperative Pervouralsky (Pervouralsk urban district), and Agrofirm Artyemovsky LLC (Artyemovsky Region) in 1300 pairs of Black Pied Holsteins of Ural type. Tie-up housing of cattle with milking through milk line is used by the above enterprises. Cattle were fed according to standard diets. Cattle groups included cows from the 1^{st} to 2^{nd} calving and servicing bulls. These were 200 cows and 10 bulls in Mezenskoye LLC, 400 cows and 11 bulls in Agricultural Breeding Cooperative Pervouralsky, and 900 cows and 15 bulls in Agrofirm Artyemovsky LLC. Pairs for artificial insemination were formed out of these animal groups.

Blood groups were assayed as per P.F. Sorokov [37]. Material for analysis was collected once from the tail vein by single-use vacuum blood collection system in animals aged over 6 months. Blood antigens were found by hemolysis test (dissolution of erythrocytes under the effect of specific antiserum at presence of complement). Antiserums were produced at immunization of recipient animals by donor blood; complement was collected from the rabbit blood serum. Total 54 monospecific serums were used for identification of 11 blood groups systems.

Index of antigen similarity of cows with mated bulls was the main cow grouping criteria based on the aggregate of blood antigens. Index of antigen similarity C_{as} was calculated by formula of S.I. Shadmanov [38]:

$$C_{as} = (A_{bi} + A_{ci})/(A_b + A_c),$$

where A_{bi} and A_{ci} are the amounts of similar mother and father antigens, A_b is the number of identified father antigens, A_c is the number of identified mother antigens.

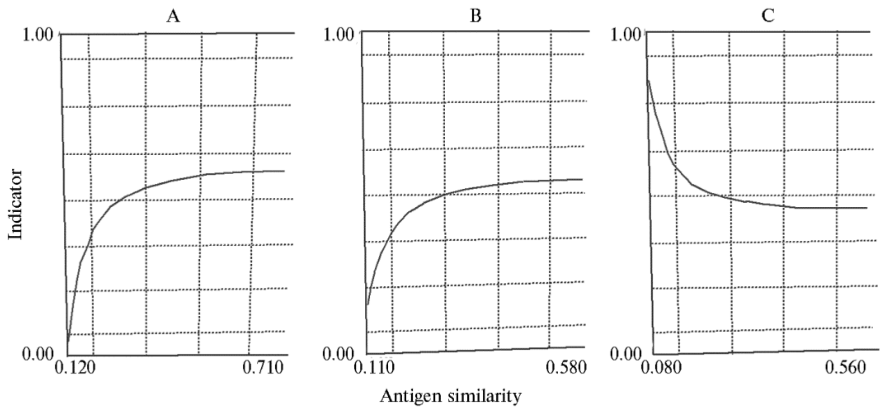
Homozygosity in parent pairs was accounted by blood group systems EAA, EAF, and EAZ.

The following values were accounted for at assessment of the reproductive properties in cows: period from calving to successful insemination, fertilization index, number of abortions, survivability of calves, and multiple pregnancies.

Software packages Snedecor V3.5 and Microsoft Excel were used for biometrical processing. Mean values of reproduction indicators by samples (*M*), standard errors of the mean (±SEM) were used, statistical significance was assessed at $p \leq 0.05$; $p \leq 0.01$, and $p \leq 0.001$, and correlation coefficients between the studied reproduction indicators and antigen similarity of pairs were calculated.

Results. Fertility is genetically transmitted, whilst propensity for abortions and dead-born calves is also conditioned upon the genetic and immunologic factors [10, 17, 18, 29]. Total 3 % of dead-born calves and 2 % of abortions were registered in population of Agricultural Breeding Cooperative Pervouralsky amongst the calves, 5 and 2 % were registered in Mezenskoye LLC, and 2 % and 0.2 % were registered in Agrofirm Artyemovsky LLC. Abortions and dead-born calves, even in such insignificant quantities, decrease the calf yield due to which breeding enterprises suffer economic losses. Simultaneous birth of two and more female calves results in growth of the number of calves by 100 cows and is a desired sign.

We have revealed weak positive relations between the antigen similarity in pairs and abortions ($r = 0.2$, $p \leq 0.05$), as well as dead-born calves ($r = 0.1$, $p \leq 0.05$) and negative correlation between antigen similarity in pairs and birth of twins ($r = -0.14$, $p \leq 0.05$). Loss of calves may be slightly reduced and birth of twins may be slightly increased at mating of bulls and cows with high antigen similarity [35]. An observed effect of the antigen similarity on survivability of calves is 1-4 %.



Reproductive indicators in of Black Pied Holstein Ural cattle depending on antigen similarity of parent pairs: A — abortions, B — dead-born calves, C — birth of twins (Sverdlov Region, 2009-2014).

Figure (A) displays the dynamic changes in survivability of calves depending on antigenic similarity of mated animals. Change of function from 0.00 to 1.00 shows the growth in abortion probability. Number of abortions had sharply increased at index of antigen similarity in pairs of up to 10 %. With increase of the antigen similarity indicator (> 20 %), survivability of calves was growing in stepwise manner. At the same time, probability of dead-born calve had increased with increasing of the antigen similarity (see Fig., B). Significant growth in dead birth frequencies is established at antigen similarity of up to 10 %, whereas at further growth of C_{as} dead birth frequency is slightly growing. Calf loss trend at close antigen similarity is, apparently, due to the fact that recessive parent alleles with unfavorable phenotype effects merge into homozygotous state as it occurs, for instance, in case of BLAD and CVM [14]. Increase of antigen similarity in bull and cow pairs had also resulted in decrease of twin birth frequency (see Fig., C) (0.00 at graph means absence of multiple pregnancies, 1.00 means birth of twins). At similarity index of < 0.1, number of twins was maximum. At increase of antigen similarity in parents to values of over 10 %, probability of twin birth slightly reduces.

Index of antigen similarity in the mated animals not exceeding 0.10 is optimal to decrease the calf loss and to promote twin birth. Regardless of weak correlation, the entire sample shows trend towards the better survivability of calves at antigen similarity index in bull and cow of 10 %. The use of cattle pairs with 11-20 % similar antigens gives a noticeable loss of calves.

An increase of propensity for spontaneous abortions and dead-burn calves is characteristic of some cows [20, 39]. It is necessary to identify and withdraw them from the population to increase the calf yield by 100 cows. Conversely, animals propensive for birth twins are selected for breeding. Daughters of such cows are also more propensive for birth twins [22]. This approach promotes health care and growth of cattle population at exception of free martinisme cases (different sex twins). Besides, it is required to select cows with significant milk yields for production of breeds with the highest milk yield. Such indicator is affected by genetic and feeding factors. It should be noted that sensitivity in cows to environment factors growth with increase of the genetic productivity potential in cows [40].

Antigen similarity, surely, affects the reproduction and production indicators in animals. At that, separate antigens or blood group systems often control certain traits significantly more than others [31]. Similarity in parents in one system may result in improvement of indicators, whereas may result in deterioration in the other one. We have analyzed the relationships between homo- and heterozygosity by A, F/V, Z blood group systems and duration of the period from calving to successful insemination by fertilization index and calf survivability index. These systems consist of one-two antigens. This enables us to track presence or absence of immunological conflict between the mother cow and calf by certain antigens.

Among the studied animals we revealed A_1 and A_2 antigens of EAA blood group. The following mother and father antigen combinations are found: homozygotes A_1/A_1, A_2/A_2, A_1A_2/A_1A_2, no antigens (–/–); heterozygotes A_1/A_2, A_1A_2/A_2, A_1A_2/A_1, A_1A_2/–, A_1/–, A_2/–. Period from calving to successful insemination for EAA homozygous animals from Agricultural Breeding Cooperative Pervouralskiy and Argofirm Artyemovskiy LLC is longer compared to that for heterozygous ones (see Table). Abortions and dead-born calves amongst homozygous pairs are more frequent (by 2.5 and 0.3 %, respectively) than amongst heterozygotes, that is due to a greater genetic similarity of EAA system parent antigens. At the same time, number of twins from homozygous pairs is significantly higher (3.3 %).

EAF system in the sample consists of F and V antigens. Antigen F is practically found in all animals of the sample, while antigen V is present only in few animals. Both blood antigens are rarely found. The sample contains homozygotes F–/F–, V–/V–, FV/FV, –/– and heterozygotes F–/V–, FV/F, FV/V, FV/–. As to EAF system, the homozygous pairs in all studied enterprises are more numerous than heterozygous pairs (see Table). Survivability of calves from homozygous pairs was less than from heterozygous. Frequencies of abortions, dead-born calves and multiple pregnancies in homozygous pairs are 1.9; 4.8, and 2.9 %, respectively. That is, selection of EAF heterozygous pairs leads to better survivability of calves. However, frequency of twin births was 0.7 % lower. Most healthy calf was produced in combination of F or F/V antigens from bull and V antigen from cow. Insufficient heterogeneity of blood groups results in calf loss. High frequency of twin birth was at mating bulls and cows with the same EAF system antigens.

EAZ blood system antigen groups among the studied animal populations were heterozygotes Z/– and homozygotes Z/Z, –/–. Total number of pairs homozygous for EAZ blood system antigens in all populations was 442, that is 102 more compared to heterozygous pairs (see Table). Period from calving to successful insemination among homozygous pairs from Argofirm Artyemovskiy LLC is 90 days that is 3 days shorter compared to heterozygous ones. In ABC Pervouralskiy, this period in heterozygous pairs was also longer than in homozygous pairs by 6 days. That is, we have revealed the trend towards a decrease in the interval from calving to successful insemination in mating animals homogenous for EAZ system. According to V.K. Milovanov at al. [39], immunologic conflict occurring due to lack of Z antigen in one parent and presence in the other parent results in insemination problem. There are cases when at insemination embryo is lost in the first months of pregnancy. Among the studied populations, abortions and dead births are more often from EAZ-heterozygous pairs.

Reproductive indicators depending on combinations of parents by blood group systems in Black Pied Holsteins of Ural type (M±SEM, Sverdlov Region, 2009-2014)

Indicator	Mezenskoye LLC	ABC Pervouralskiy"	Agrofirm Artyemovskiy LLC	Total, mean value
		E A A system		
		Homozygous pairs		
Number of pairs	26	40	113	179
Period from calving to successful insemination, days	87.0±2.0	106,0±3,0*	93,0±2,0	95,0±1,0
Fertilization index	1.30±0.10	1,17±0,30	1,20±0,20**	1,22±0,30
Number (%) of abortions		6 (3.3 %)		
Number (%) of dead-born calves		7 (3.9 %)		
Multiple pregnancy (twins), number (%)		6 (3.3 %)		
		Heterozygous pairs		
Number of pairs	95	88	421	604
Period from calving to successful insemination, days	90.6±2.0	82,9±3,0	90,9±1,0	88,1±3,0
Fertilization index	1.32±0.10	1,13±0,20	1,14±0,10	1,19±0,10
Number (%) of abortions		5 (0.8 %)		
Number (%) of dead-born calves		22 (3.6 %)		
Multiple pregnancy (twins), number (%)		17 (2.8 %)		
		E A F system		
		Homozygotous pairs		
Number of pairs	67	81	269	417
Period from calving to successful insemination, days	83.0±1.0	95,0±3,0**	92,0±2,0	90,0±2,0
Fertilization index	1.32±0.20	1,13±0,20	1,14±0,20	1,19±0,10
Number (%) of abortions		8 (1.90 %)		
Number (%) of dead-born calves		21 (4.80 %)		
Multiple pregnancy (twins), number (%)		12 (2.90 %)		
		Heterozygous pairs		
Number of pairs	54	47	262	363
Period from calving to successful insemination, days	94.0±3.0	70,0±2,0	92,0±3,0	85,5±2,0
Fertilization index	1.43±0.10***	1,12±0,10	1,12±0,20	1,22±0,30
Number (%) of abortions		2 (0.55 %)		
Number (%) of dead-born calves		8 (2.20 %)		
Multiple pregnancy (twins), number (%)		8 (2.20 %)		
		E A Z system		
		Homozygotous pairs		
Number of pairs	67	72	303	442
Period from calving to successful insemination, days	88.0±2.0	80,0±1,0	90,0±3,0	86,0±3,0
Fertilization index	1.34±0.30	1,22±0,10	1,10±0,20	1,22±0,20
Number (%) of abortions		6 (1.4 %)		
Number (%) of dead-born calves		14 (3.2 %)		
Multiple pregnancy (twins), number (%)		6 (1.4 %)		
		Heterozygous pairs		
Number of pairs	54	56	230	340
Period from calving to successful insemination, days	87.0±3.0	84,0±2,0	93,0±2,0	88,0±3,0
Fertilization index	1.34±0.10	1,19±0,10	1,18±0,30	1,37±0,20
Number (%) of abortions		5 (1.5 %)		
Number (%) of dead-born calves		16 (4.7 %)		
Multiple pregnancy (twins), number (%)		6 (1.8 %)		

, **, * Differences between the heterozygous and homozygous pairs are statistically significant at p ≤ 0.05; p ≤ 0.01 and p ≤ 0.001, respectively.

Thus, reproductive properties of Holstein Black Pied cattle depend on blood group similarities of the parents. Association of blood group system antigens with a certain trait can be more pronounced compared to other traits. At similarity of the parents, one blood antigen system can be associated with improved reproduction, whereas the other one have negative effects. There is a trend towards better survivability of calves from heterozygous pairs for EAZ system (i.e. a 2.5-2.7 % reduced number of dead-born calves and 0.3-1.4 % less abortions). Apparently, it is an immunologic conflict that results in death of calves. We also have discovered trend towards improved survivability of the calves and an increase in animal populations at 10 % antigenic similarity of parents.

REFERENCES

1. Palaniappan S. Blood grouping in animals. *The Hindu Online edition of India's National Newspaper*, 2004, 9: 61.
2. Shukyurova E.B. *Open Scientific Bulletin*, 2014, 1: 1-5 (in Russ.).
3. Foster M. Genomanaliyse. In: *Tierzucht und allgemeine Landwirtschaftslehre fur Tiermediziner.* H. Kräusslich, G. Brem (eds.). Enke, 1997: 77-109.
4. Buvaeva N.V. *Ispol'zovanie grupp krovi v selektsii krupnogo rogatogo skota kalmytskoi porody. Avtoreferat kandidatskoi dissertatsii.* [Use of blood groups in the selection of cattle of Kalmyk breed. PhD Thesis]. Stavropol', 2012 (in Russ.).
5. Charoensook R., Knorr C., Brenig B., Gatphayak K. Thai pigs and cattle production, genetic diversity of livestock and strategies for preserving animal genetic resources. *Maejo Int. J. Sci. Tech.*, 2013, 1: 113-132.
6. Serdyuk G.N., Katalupov A.G. *Zootekhniya*, 2008, 8: 8-10 (in Russ.).
7. Neves J.P., Miranda K.L., Tortorella R.D. Scientific progress in reproduction research during the first decade of XXI century. *Revista brasileira de zootecnia*, 2010, 1: 414-421 (in Russ.).
8. Van Eetvelde M., Heras S., Leroy J.L.M.R., Van Soom A., Opsomer G. The importance of the periconception period: immediate effects in cattle breeding and in assisted reproduction such as artificial insemination and embryo transfer. In: *Periconception in physiology and medicine. Advances in experimental medicine and biology.* A. Fazeli, W. Holt (eds.). Springer, Cham, 2017, V. 1014: 41-68 (doi: 10.1007/978-3-319-62414-3_3).
9. Shkuratova I.A., Donnik I.M., Nevinnyi V.K., Shusharin A.D., Vereshchak N.A., Ryaposova M.V., Belyaev I.P., Sbitnev E.V. *Veterinariya*, 2007, 7: 14-15 (in Russ.).
10. Purfield D.C., Bradley D.G., Berry D.P., Evans R.D., Kearney F.J. Genome-wide association study for calving performance using high-density genotypes in dairy and beef cattle. *Genet. Sel. Evol.*, 2015, 1: 47 (doi: 10.1186/s12711-015-0126-4).
11. Oleshko V.P., Babenko E.I. *Tekhnologiya virobnitstva i pererobki produktsiї tvarinnitstva*, 2014, 1: 66-69 (in Russ.).
12. Fisher M., Small B., Roth H., Mallon M., Jerebine B. What do individuals in different science groups within a life sciences organization think about genetic modification? *Public Underst. Sci.*, 2005, 3: 317-326 (doi: 10.1177/0963662505048594).
13. Rodríguez F.M., Salvetti N.R., Panzani C.G., Ortega H.H., Rey F., Barbeito C.G. Influence of insulin-like growth factor-binding proteins-2 and -3 in the pathogenesis of cystic ovarian disease in cattle. *Anim. Reprod. Sci.*, 2011, 1-4: 1-10 (doi: 10.1016/j.anireprosci.2011.08.007).
14. Kumar V., Chakravarty A.K. Genetic disorders in dairy cattle: an Indian perspective. *Indian J. Anim. Sci.*, 2015, 8: 819-827.
15. Shendakov A. Improvement system of biological factors management in the breeding of farm animals. *Russian Journal of Agricultural and Socio-Economic Sciences*, 2012, 12: 3-18.
16. Masalov V.N., Enin Yu.M., Sinitsyn A.N., Kozlov A.S. *Vestnik Orlovskogo gosudarstvennogo agrarnogo universiteta*, 2007, 1: 23 (in Russ.).
17. Gukezhev V.M., Gabaev M.S., Batyrova O.A. *Agrarnyi vestnik Urala*, 2012, 7: 42-44 (in Russ.).
18. Flisikowski K., Schwarzenbacher H., Fries R., Venhoranta H., Flyckt A., Taponen J., Andersson M., Nowacka-Woszuk J., Szczerbal I. Switonski M., Mckay S.D., Schnabel R., Taylor J.F., Lohi H. A novel mutation in the maternally imprinted *PEG3* domain results in a loss of *MIMT1* expression and causes abortions and stillbirths in cattle (*Bos taurus*). *PLoS ONE*, 2010, 11: e15116 (doi: 10.1371/journal.pone.0015116).
19. Wolf E., Bauersachs S. Functional genome research in reproductive biology and biotechnology — a minireview. *Animal Sci. P.*, 2010, 2: 123-132.
20. Gabaev M.S., Gukezhev V.M. Plodovitost' i plemennaya tsennost' korov. *Agrarnyi vestnik Urala*, 2011, 7: 33-34.
21. Musallyamova M.F., Antonova N.V. Calculation of product costs of dairy cattle breeding in Russia. *Mediterranean Journal of Social Sciences*, 2014, 24: 403-406 (doi: 10.5901/mjss.2014.v5n24p403).
22. Pronina M.Yu. *Uchetnye zapisi Kazanskoi gosudarstvennoi akademii veterinarnoi meditsiny imeni N.E. Baumana*, 2012, 12: 358 (in Russ.).
23. Ilshatovna S.A., Vildanovna N.R. Application of fuzzy-set and multiple approaches in evaluation of effectiveness of agricultural industry enterprises activities (as an example of animal breeding of the Republic of Tatarstan). *Biosciences Biotechnology Research Asia*, 2014, 11: 37-42.
24. Smith R.L., Groen Y.T., Strawderman R.L., Schukken Y.H., Pradhan A.K., Wells S.J., Espejo L.A., Whitkock R.H., Van Kessel J.S., Smith J.M., Wolfgang D.R. Effect of Johnes disease status on reproduction and culling in dairy cattle. *J. Dairy Sci.*, 2010, 8: 3513-3524 (doi: 10.3168/jds.2009-2742).

25. Bozymov K.K., Nassambayev E., Bayakhov A.N., Upievich B.Y., Sultanova A.K. Experience of using ultrasonography in the diagnosis of cattle reproductive track diseases in the West Kazakhstan region. *Biomedical and Pharmacology Journal*, 2015, 1: 21-25 (doi 10.13005/bpj/577).
26. Wickramasinghe S., Rincon G., Medrano J.F. Variants in the pregnancy-associated plasma protein-a2 gene on *Bos taurus* autosome 16 are associated with daughter calving ease and productive life in holstein cattle. *J. Dairy Sci.*, 2011, 3: 1552-1558 (doi: 10.3168/jds.2010-3237).
27. Goncharenko I.V., Vinnichuck D.T. *Haukovii visnik NUBiP Ukraïni. Seriya: Tekhnologiya virobnitstva i pererobki produktsiï tvarinnitstva*, 2015, 205: 264-273 (in Russ.).
28. Bushueva İ.V., Knysh E.G., Panasenko O.İ. Doslidzhennya likuval'noï efektivnosti morfolinii 2-[5-(piridin-4-il)-1,2,4-triazol-3-iltio] atsetatu pri khvorobakh deyakikh vidiv tvarin. *Sciencerise*, 2014, 1: 100-104.
29. Aleshkin V.A., Lozhkina A.N., Zagorodnyaya E.D. *Immunologiya reproduktsii* [Immunology of reproduction]. Chita, 2004 (in Russ.).
30. Pfeffer P.L., Pearton D.J. Trophoblast development. *Reproduction*, 2012, 3: 231-246 (doi: 10.1530/REP-11-0374).
31. Politkin D.Yu. *Zootekhniya*, 2011, 5: 6-7 (in Russ.).
32. Gridina S.L., Shatalina O.S. *Dostizheniya nauki i tekhniki APK*, 2011, 6: 69-70 (in Russ.).
33. Gridina S.L., Romanenko G.A. *Vestnik Kurganskoi GSKHA*, 2013, 4: 29-31 (in Russ.).
34. Gridin V.F., Tkachenko I.V. Gridina S.L. *Vestnik Kurganskoi GSKHA*, 2013, 1: 140-42 (in Russ.).
35. Starodumov I.M., Panina S.V. *Estestvennye i tekhnicheskie nauki*, 2008, 4: 96-97 (in Russ.).
36. Kerro L.V. *Ispol'zovanie antigenov grupp krovi v plemennoi rabote s cherno-pestrym skotom Zaural'ya. Avtoreferat kandidatskoi dissertatsii* [Use of blood group antigens in breeding black-motley cattle of the Trans-Urals. PhD Thesis]. Kurgan, 2006 (in Russ.).
37. Sorokovoi P.F. *Metodicheskie ukazaniya po issledovaniyu i ispol'zovaniyu grupp krovi v selektsii krupnogo rogatogo skota* [Methodological guidelines for the study and use of blood groups in cattle breeding]. Dubrovitsy, 1974 (in Russ.).
38. Shadmanov S.I., Stolbov V.M., Pepina G.D. V sbornike: *Novoe v razvedenii i genetike sel'skokhozyaistvennykh zhivotnykh* [New facets in the breeding and genetics of farm animals]. St. Petersburg, 1973 (in Russ.).
39. Milovanov V.K., Sokolovskaya I.I. *Zhivotnovodstvo*, 1964, 6: 75-83 (in Russ.).
40. Voroshilova E.D. *Sibirskii vestnik sel'skokhozyaistvennoi nauki*, 2007, 1: 120-121 (in Russ.).