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GENETIC ANALYSIS OF LINES OF HORSES OF THE HUTSUL BREED OF DOMESTIC SELECTION

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The article presents the results of an extended study and analysis of the immunogenetic profile of lines of populations of horses of the Hutsul breed in Ukraine.

Considerable work is being carried out to preserve, improve and reproduce small breeds of horses, one of which is the Hutsul breed.

The distribution of genetic variability, genetic structure between lines of the Hutsul breed of horses and the transmission of alleles to descendants from the ancestors were studied using certification by polymorphic blood groups.

A comparison of gene frequencies according to the spectrum of alleles of the main D-system of blood groups of the lines of the Hutsul horse breed of domestic selection was carried out. It was established that in the Goral line (stag-breeding stallion 85 Pedro) the highest frequency of the Ddk allele ($q=0.667$). High frequency of the Ddk allele in the Grobi line from the heir of the breeding stallion Grobi XV-10 SK/Aster ($q=0.500$), and throughout this line ($q=0.431$). In the Gurgul line the highest frequency of the Dcgm allele ($q=0.357$). High frequency of the Dcgm allele in the lines of Ousora (Poland) (stag-breeding stallion 52 Warnik 255) and Gurgul (stag-breeding stallion 81 Orlyk 024) ($q=0.400-0.529$), respectively. The Ousor line from the heir of the stud stallion 82 Ousor Vulkan is characterized by a high frequency of the Ddg allele ($q=0.500$) and throughout this line ($q=0.435$).

The highest genetic indicators were obtained in the Gurgul line, the level of polymorphism ($N_e = 3.960$), the lowest in the Goral line ($N_e = 2.051$). The Goral line (stable stallion 85 Pedro) has the highest expected homozygosity coefficient ($C_a = 0.488$), the lowest in the Gurgul line ($C_a = 0.253$).

The differences identified in the spectrum of active alleles of polymorphic blood group systems indicate that each studied genealogical line of horses has a certain "genetic passport", which creates a practical information base for keeping lines and the breed as a whole in Ukraine under genetic control.

Keywords: horses, lines, Hutsul breed, alleles, frequency, genotypes, genetic indicators

ГЕНЕТИЧНИЙ АНАЛІЗ ЛІНІЙ КОНЕЙ ГУЦУЛЬСЬКОЇ ПОРОДИ ВІТЧИЗНЯНОЇ СЕЛЕКЦІЇ

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В статті викладено результати розширеного вивчення та аналізу імуногенетичного профілю ліній популяцій коней гуцульської породи в Україні.

Проводиться значна робота по збереженню, вдосконаленню та відтворенню малочисельних порід коней, однією із них є гуцульська порода.



Розподіл генетичної мінливості, генетичної структури між лініями гуцульської породи коней та передача алелів нащадкам від родоначальників вивчали за допомогою атестацію за поліморфними групами крові.

Здійснено порівняння генних частот за спектром алелів основної D-системи груп крові ліній коней гуцульської породи вітчизняної селекції. Встановлено, що у лінії Горала (жеребець-плідник 85 Педро) найвища частота алелю D^{dk} ($q=0,667$). Висока частота алелю D^{dk} у лінії Гробі від спадкоємця жеребця-плідника Гробі XV-10 SK/Астор ($q=0,500$), а по всій цій лінії ($q=0,431$). В лінії Гургула найвисока частота алелю D^{csm} ($q=0,357$). Висока частота алелю D^{csm} у лінії Оусора (Польца) (жеребець-плідник 52 Варнік 255) та Гургула (жеребець-плідник 81 Орлик 024) ($q=0,400-0,529$) відповідно. Для лінії Оусора від спадкоємця жеребця-плідника 82 Оусор Вулкан характерна висока частота алелю D^{dg} ($q=0,500$) та по всій цій лінії ($q=0,435$).

Найвищі генетичні показники були одержані в лінії Гургула рівень поліморфності ($Ne - 3,960$), найнижчий в лінії Горала ($Ne - 2,051$). В лінії Горала (жеребець-плідник 85 Педро) найвищий коефіцієнт очікуваної гомозиготності ($Ca - 0,488$), найнижчий в лінії Гургула ($Ca - 0,253$).

Виявлені відмінності за спектром діючих алелів поліморфних систем груп крові вказують, що кожна досліджена генеалогічна лінія коней володіє певним «генетичним паспортом», що створює практично інформаційну базу для ведення ліній та в цілому породи в Україні під генетичним контролем.

Ключові слова: коні, лінії, гуцульська порода, алелі, частота, генотипи, генетичні показники

The Hutsul horse breed is one of the few unique breeds in Ukraine. With a limited gene pool of populations of this breed, it is a national achievement in horse breeding of domestic selection. Unfortunately, little attention is now paid to it, as to all breeds in Ukraine, responding to the issues of society and the requirements of the time. But with the preservation and thorough genetic study of its small number in Ukraine and in European countries, where the foreign gene pool of this population is located, we will be able to research and transfer experience to other generations of our society in parallel.

As a result of studying the genetic structure of Hutsul horses, it was established that the lines arose at the beginning of the 17th century, which originated from the crossing of horses of southern and Mongolian origin in harsh mountain conditions. According to the outstanding ancestors, the lines of Goral, Gurgul, Grobi, Ousor, Polyana and Pietrosu were formed.

According to the State Stud Book Volume II (Holovach M. Y., 2013), the first line of the Hutsul breed was the line of the stallion Goral in the Lviv region, which was the main one and from it came 7 stallions and 70 mares. In parallel, another line of the stallion Grobi was established in Bukovina. From it came at that time 6 stallions and 28 mares, which were recorded in the registration book.

In the period between the First and Second World Wars, new lines were emerging, one of them was the Gurgul line (Romanenko G.V. (2018). During the same period, the lines already had more licensed offspring of stallions, from the Goral line - 18, Grobi - 13, Gurgul - 47. Now, in the post-war period, three genealogical lines of Goral, Grobi and Gurgul were recognized in this breed.

Today, there are representatives of 5 lines of the Hutsul breed in Ukraine: Gurgul, Grobi, Goral, Ousora, Pietrosu (Golovach M. Y., 2010).

From many years of selection work, genetic analysis and certification of the Hutsul horse breed by blood group (Zaderykhina O. A., 2017, Rossokha V. I., 2010),



monitoring, (Podoba B. E., 2012) researchers determine that The gene pool of the Hutsul breed combines the features inherent in riding and trotting breeds.

It is also extremely important in this work that in-depth immunogenetic analysis provides a real opportunity not only to track the movement of markers across generations, but also to control the inheritance of genes from the ancestor to his valuable successors. As it was studied in the works of various researchers (Popadiuk S.S., 2019; Podoba B. E., 2013; Efimenko M. Ya., 2005; Parasochka I. F., 2007), not only to use the latest PCR methods (Behl R., 2007; Georgescu S.E., 2011; Račkauskaitė A., 2021; Szilvia Kusza, 2013; Stachurska A., 2014; Xu L.X., 2012), but also in parallel immunogenetic methods for blood groups, which complement each other (Mihók S., 2005).

The level of polymorphism is an important integral indicator that determines the number of actively acting alleles in the line (Altukhov Yu. P., 1996). So are other indicators of the genetic situation in the animal population.

Due to the high working capacity of horses of this breed in specific mountainous and foothill areas of the Carpathian region, the development of rural tourism and methods of hippotherapy of a number of nervous diseases, and taking into account the balanced temperament, endurance, well-developed herd instinct, authentic need for contact with humans, horses of the small Hutsul breed need to be studied and the gene pool preserved. One of the components of scientific support for the preservation of the gene pool is the identification of the gene structure according to polymorphic blood group systems.

The purpose of the research is to investigate genetic markers and genetic indicators of the lines of the Hutsul breed of horses of Ukrainian selection.

Materials and methods of research. Immunogenetic studies of the D-system of blood groups were performed on 96 blood samples of the Hutsul breed of horses of domestic selection.

Immunogenetic certification of horses by blood groups was carried out according to generally accepted methods (Burkat V. P., 2010; Hopka M. V., 2007; Rossokha V. I., 2016), (SOU 01.22-37-528: 2006.)ⁱⁱ. Serological testing was used to determine erythrocyte alleles of complex polymorphic systems A and D, and monofactor systems C and K. For differentiation of erythrocyte alleles, monospecific serum reagents were used, which were identified with international standards (DSTU ISO 8531:2015)ⁱⁱⁱ.

According to the results of testing and determination of genotypes, an analysis of the immunogenetic structure of the studied horses of 4 lines of progenitor stallions was carried out by antigens and alleles of blood groups, and the transmission of marker alleles to the descendants of these genealogical lines.

Genetic analysis of the frequency of occurrence of alleles of polymorphic blood groups and genetic indicators (level of polymorphism (Ne); coefficient of expected (Ca) and actual homozygosity (H) for all loci; indicator of homozygosity realization (W); deficiency of homozygotes (Def); information index (I), observed (Ho) and expected (He) heterozygosity; unbiased expected heterozygosity (uHe); Wright's fixation index F (Fis)) of genealogical lines as a whole, as well as for the descendants of stud stallion of these

ⁱⁱ SOU 01.22-37-528: 2006. Livestock. method for determining blood groups, polymorphic blood proteins and expertise of the origin of pedigree horses. Kyiv: Ministry of Agrarian Policy of Ukraine, 2006. 26 p. (Standard of the Ministry of Agrarian Policy of Ukraine)

ⁱⁱⁱ DSTU ISO 8531:2015. Livestock.horses.methods for obtaining and storage of anti-erythrocyte immunodiagnostics for identification of horses by polymorphic blood group systems. [Valid from 2017-07-01]. Kyiv, 2015. 17 p. (Information and documentation).



lines of the Hutsul breed were calculated by generally accepted methods using the programs "Excel 2003", "GenAIEx 6.502" and "Statistica".

Research results. We have 5 lines, namely Grobi, Ousora, Gurgul, Goral and Pietrosu. The last line of Pietros continues with a descendant of the stud stallion 86 Pers, bay-piebald, born in 2003 (sire 211 Baca, dam 23 GKr Perunka, owner of the National Breeding Center "Plemkonetsentr"). Only two mares are certified in this line. It is not possible to trace the stallions.

To date, we have studied only the first four lines.

The Grobi line is the first branched line with which work is being carried out in Ukrainian stud farms. It comes from the stallion Grobi, light bay, born in 1895 (in Bukovina).

His descendant is a stallion-breeder 84 Pegazik UA210000251, light bay, born in 2001 (father 10 GRz Lunak, mother 138 GRz Pelagia), place of birth Poland (PL), owner of the National Breeding Association "Plemkonetsentr". And the second descendant of Grobi XV-10 SK/Astor, bay, 2011 (sire 4566 Grobi XV/ Grobi XII) birthplace and owner of the NVA "Plemkonetsentr".

The second line of Ousor from a bay stallion born in 1929 (in Bukovina). His descendants in the Ousor line are the stud stallions 82 Ousor Vulkan HL050870000, mouse-colored, born in 2005, (father 3653 Ousor, mother 730 Grobi XXI-36), birthplace Hungary (H), owner FG "Polonynske gospodarstvo" and the second descendant stud stallion 52 Varnik 255, bay, born in 2002, (father 25 GRz Lotnik, mother 77 GRz Wartka), birthplace Poland (PL), owner FG "Zarechie".

The third line is Gurgul, born in 1924 (in Eastern Slovakia). His descendants in the Gurgul line are the stud stallions 74 Merkur Gu E 2-8, bay, born in 1985, (father Gurgul Edo II, mother 16 Dubrava Gu V-5), birthplace Czechoslovakia, owner Yaremche National Park, the second descendant 81 Orlyk 024, bay, born in 2004, (father 54 Viter 048, mother 560 Ghilka 051), birthplace FG "Polonynske Gospodarstvo", owner FG "Polonynske Gospodarstvo" and the third descendant 69 Lukash Gu E-2-8, bay, born in 1984, birthplace Czechoslovakia, owner SFG "Maximov", who unfortunately died in 2001. He has a descendant of the stud stallion 47 Borzy, igrene suit, born in 1995, owner of the KVI "Varto" from which he has 2 offspring stallions and 1 mare. And mainly from 69 Lukash only heiresses.

And the fourth line of Goral from a Karak stallion, born in 1899 (in the Hutsul region). His descendants in the Goral line are the stud stallion 85 Pedro UA210000250, bay suit, born in 2002, (father 77 GKr Sputnik, mother 72 GKr Panienko), place of birth Poland (PL), owner of the NVA "Plemkonetsentr".

So we have 5 lines, namely Grobi, Ousora, Gurgul, Goral and Pietrosu. The last line of Pietros continues with the offspring of the stallion-breeder 86 Pers, bay-piebald, born in 2003 (father 211 Baca, mother 23 GKr Perunka, owner of the National Breeding Association "Plemkonetsentr"). Only two mares have been certified in this line. It is not possible to trace the stallions.

Today, these four lines are large and remain the leading ones in the Hutsul horse breed (table 1). They have breeding qualities and a large number of stallions-breeders. And the Gurgul line is slowly passing through the daughters of the stallion-breeder 81 Orlyk 024 into the Ousor line through the stallion-breeder 82 Ousor Vulkan.



Table 1

Number of certified stallions and mares by genealogical line branches

Line	Total horses in line, head.	Including		The most promising branches in the lines	Of them, the main production stock of horses, head.						
		Breeding stallions	Mares		total	Including					
						sons	grandchildren	great-grandchildren	daughters	granddaughters	great-granddaughters
Groby	2	2	-	84 Pegasic	63	31	2	-	30	-	-
				Groby XV-10 SK/Astor	7	3	-	-	4	-	-
Ousora	2	2	-	82 Ousor Vulkan	52	16	2	-	34	-	-
				52 Varnik 255	17	5	-	-	12	-	-
Gurgula	3	3	-	81 Orlik 024	46	17	-	-	29	-	-
				74 Merkur Gu E 2-8	22	3	8	-	2	9	-
				69 Lukas Gu E-2-8	13	1	2	-	9	1	-
Gorala	1	1	-	85 Pedro	24	9	-	-	15	-	-

The largest number of certified offspring of stallions and mares in the Gurgul line is 81 animals, the average in Grobi is 70 animals and in Ousor is 69 animals. The fewest animals have been certified in the Goral line – 24 (Table 2).

Thus, the largest number of offspring of stallions is traced in the Grobi line from the stud stallion 84 Pegazik – 33 and the Ousor line from the stud stallion 82 Ousor Vulkan – 18.

The Ousor line from the heir of the stud stallion 82 Ousor Vulkan is characterized by a high frequency of the Ddg allele ($q=0.500$) and throughout this line ($q=0.435$) (Table 3). The highest frequency of the Ddk allele is in the Goral line (stud stallion 85 Pedro) ($q=0.667$). The high frequency of the Ddk allele is in the Grobi line from the heir of the stallion-stud stallion Grobi XV-10 SK/Aster ($q=0.500$) and throughout this line ($q=0.431$).

The highest frequency of the Dcgm allele in the entire Gurgul line ($q=0.357$). High frequency of the Dcgm allele in the Ousor (Poland) (stag-breeding stallion 52 Warnik 255) and Gurgul (stag-breeding stallion 81 Orlyk 024) lines ($q=0.400-0.529$) respectively.

The highest frequency of the Dd allele in the Grobi line from the heir of the Grobi XV-10 SK/Astor ($q=0.500$).



Table 2

The number of certified stallions-breeders and mares in the section of branches of genealogical lines

Lines	Branch	Number of active						total
		Stallions			Mares			
		sons	grandchildren	great-grandchildren	daughters	granddaughters	great-granddaughters	
Groby	84 Pegasic	31	2	-	30	-	-	63
	Groby XV-10 SK/Astor	3	-	-	4	-	-	7
Total in the line		34	2	-	34	-	-	70
Ousora	82 Ousor Vulkan	16	2	-	34	-	-	52
	52 Varnik 255	5	-	-	12	-	-	17
Total in the line		21	2	-	46	-	-	69
Gurgula	81 Orlik 024	17	-	-	29	-	-	46
	74 Merkur Gu E 2-8	3	8	-	2	9	-	22
	69 Lukas Gu E-2-8	1	2	-	9	1	-	13
Total in line		21	10	-	40	10	-	81
Gorala	85 Pedro	9	-	-	15	-	-	24

The low frequency of the Ddk allele ($q=0.022$), Dd ($q=0.022$) was in the Ousor line, and the lowest Dd ($q=0.018$) in the Gurgul line.

The Dd and D^{bcm} alleles are absent in the Goral line. And the Dad and D^{cegm} alleles are absent in all lines of the Hutsul horse breed.

The Ousor line from the heir of the stud stallion 82 Ousor Vulkan is characterized by a high frequency of the Ddg allele ($q=0.500$) and throughout this line ($q=0.435$) (Table 3). The highest frequency of the Ddk allele in the Goral line (student stallion 85 Pedro) ($q=0.667$). The high frequency of the Ddk allele in the Grobi line from the heir of the stud stallion Grobi XV-10 SK/Aster ($q=0.500$) and throughout this line ($q=0.431$).

The highest frequency of the Dcgm allele throughout the Gurgul line ($q=0.357$). High frequency of the Dcgm allele in the Ousor lines (Poland) (student stallion 52 Warnik 255) and Gurgul (student stallion 81 Orlyk 024) ($q=0.400-0.529$), respectively.

The highest frequency of the Dd allele in the Grobi line from the heir of the stallion-breeder Grobi XV-10 SK/Aster ($q=0.500$).

The low frequency of the Ddk allele ($q=0.022$) Dd ($q=0.022$) was in the Ousor line, and the lowest Dd ($q=0.018$) in the Gurgul line.



Table 3

Distribution of gene frequencies of D-system blood group alleles by lines of Hutsul horses, M±m

Lines		Aleli							
		ad	dg	dk	cgm	bcm	de	d	cegm
Grobi (Poland)	84 Pegasik (sire Lunak) (n=33)	0,000	0,258± 0,054	0,424± 0,061	0,106± 0,038	0,076± 0,033	0,121± 0,040	0,015± 0,015	0,000
	Grobi XV-10 SK/ Astor (sire 4566 Grobi XV/ Grobi XII) (n=3)	0,000	0,000	0,500± 0,204	0,000	0,000	0,000	0,500± 0,204	0,000
	Total by line (n=36)¹	0,000	0,236± 0,050	0,431± 0,058	0,097± 0,035	0,069± 0,030	0,111± 0,037	0,056± 0,027	0,000
Ousora (Poland)	82 Ousor Vulkan (sire 3653 Ousor) (n=18)	0,000	0,500± 0,083	0,000	0,222± 0,069	0,056± 0,038	0,222± 0,069	0,000	0,000
	52 Varnik 255 (sire 25 GRz Lotnik) (n=5)	0,000	0,200± 0,127	0,100± 0,095	0,400± 0,155	0,200± 0,127	0,000	0,100± 0,095	0,000
	Total by line (n=23)²	0,000	0,435± 0,073	0,022± 0,022 ^{***} ₁	0,261± 0,065	0,087± 0,042	0,174± 0,056	0,022± 0,022	0,000
Gurgula (Czechoslovakia)	81 Orlik 024 (sire Viter 048) (n=17)	0,000	0,177± 0,065	0,000	0,529 ± 0,086	0,029 ± 0,029	0,235 ± 0,073	0,029 ± 0,029	0,000
	74 Merkur Gu E 2-8 (sire Gurgul Edo II) (n=11)	0,000	0,318± 0,099	0,318 ± 0,099	0,091 ± 0,061	0,046 ± 0,044	0,227 ± 0,089	0,000	0,000
	Total by line (n=28)³	0,000	0,232± 0,056	0,125 ± 0,044 [*] _{*1}	0,357 ± 0,064 [*] ₁	0,036 ± 0,025	0,232 ± 0,056	0,018 ± 0,018	0,000
Gorala (Poland)	85 Pedro (sire 77 GKr Sputnik) (n=9) ⁴	0,000	0,056± 0,054 ^{**} ₂	0,667 ± 0,111 [*] _{**2, **3}	0,167 ± 0,088	0,000	0,111 ± 0,074	0,000	0,000

Note: * – $P \leq 0.05$; ** – $P \leq 0.01$; *** – $P \leq 0.001$; 1 – 4 – lines of Hutsul horses here and below: 1 – Grobi line, 2 – Ousor line, 3 – Gurgul line, 4 – Goral line



The Dd and Dbcm alleles are absent in the Goral line. And the Dad and Dcegm alleles are absent in all lines of the Hutsul horse breed.

No significant difference between the values of gene frequencies of the D-system alleles of the blood groups of the Hutsul horse breed was found between the Ousor line and the Gurgul line. There is also no statistically significant difference between the Grobi line and the Goral line.

In general, no statistically significant differences were found between the allele indices. But there were differences that should be noted.

Thus, statistically significant (significant) differences were found in the Dcgm allele frequencies ($P \leq 0.05$) between the Grobi line and the Gurgul line.

When comparing the Ddk allele gene frequencies ($P \leq 0.01$) between the Gurgul line and the Grobi line, differences were found at a high level. The same trend was found between the Gurgul line and the Goral line, respectively.

According to the Ddg allele gene frequencies ($P \leq 0.01$) between the Ousor line and the Goral line, differences were found at a high level.

In comparing the gene frequency indices for the Ddk allele ($P \leq 0.001$) between the Ousor line with the Grobi line and Ousor from Goral, respectively, differences were found at the absolute level of statistical significance.

Table 4 presents stallions-breeders with homozygous and heterozygous genotypes according to the D-system of blood groups, which have the largest sample of offspring and have passed immunogenetic certification at Livestock farming institute of the NAAS.

Table 4

Genotypes according to the D-system of stud stallions of the Hutsul breed, admitted for breeding use

LINE	Breeding stallions from which the largest number of offspring was obtained	Genotypes	Number of offspring in the line			Total offspring by lines
			stallions	mares	total	
GROBY	84 Пегазік	D ^{dg/dk}	33	30	63	70
	Гробі XV-10 SK/Астор	D ^{cgm/d}	3	4	7	
OUSORA	82 Оусор Вулкан	D ^{de/dg}	18	34	52	69
	52 Варнік 255	D ^{cgm/dg}	5	12	17	
GURGULA	81 Орлик 024	D ^{cgm/de}	17	29	46	81
	74 Меркур G E 2-8	D ^{de/de}	11	11	22	
	69 Лукаш Gu E-2-8 (пав у 2001 р.)	-	3	10	13	
GORALA	85 Педро	D ^{dk/de}	9	15	24	24



So we see that in the Gurgul line there is a homozygous offspring of the stallion-breeder 74 Merkur G E 2-8.

And we state that in the Gurgul line one of the Dde alleles is inherited, because it is in the offspring of the stallions 81 Orlyk 024 and 74 Merkur G E 2-8. And in the Ousor line one of the Ddg alleles is transmitted.

A study was conducted on the inheritance of alleles of 4 lines of Hutsul horses (Table 5). Thus, in the Grobi line, the heir of the stallion-stud stallion 84 Pegazik (n=33), the Ddg allele was transmitted to his 14 offspring of stallions, and the Ddk allele to 19 offspring. But in this line, the heir of the stallion-stud stallion Grobi XV-10 SK/Astor (n=3), the Dd allele was transmitted to 3 offspring, and the Dcgm allele was not transmitted.

Table 5

Transmission of marker alleles to offspring from stud stallions of the Hutsul breed

LINE	Nickname and number according to DKPK	n, heads	Alleles		Number of offspring of stallions				χ^2
			I	II	with allele I	%	with allele II	%	
OUSURA	82 Ousor Vulcan	18	de	dg	6	33	12	67	11,845
	52 Varnik 255	5	cgm	dg	4	80	1	20	
GROBY	84 Pegasik	33	dk	dg	19	58	14	42	17,082
	Groby XV-10 SK/Astr	3	cgm	d	0	0	3	100	
GURGULA	81 Orlik 024	17	de	cgm	3	18	14	82	9,134
	74 Merkur G E 2-8	11	de	de	5	45	0	0	
GORALA	85 Pedro	9	de	dk	1	11	8	89	2,250

In the Ousor line, the heir of the stallion-stud stallion 82 Ousor Vulkan (n=18), the Dde allele was transmitted to 6 offspring of stallions, and the Ddg allele to 12 offspring. In the same line, in the heir of the stallion-stud stallion 52 Varnik 255 (n=5), the Ddg allele was transmitted to one offspring, and the Dcgm allele was transmitted to 4 offspring.

In the Gurgul line, in the heir of the stallion-stud stallion 81 Orlyk 024 (n=17), the Dde allele was transmitted to 3 offspring, and the Dcgm allele to 14 offspring. In the same line, in the heir of the stallion-stud stallion 74 Merkur Gu E 2-8 (n=11), the Dde allele was transmitted to only 5 offspring.



But in the Goral line, in the heir of the stallion-stud stallion 85 Pedro (n=9), the Ddk allele was transmitted to 8 offspring, and the Dde allele to one.

A genetic and population analysis of 4 lines of stallions-stud stallion of the Hutsul breed was conducted.

Genetic indicators of genealogical lines of the Hutsul breed were calculated by lines as a whole, as well as by the descendants of the stallions-stud stallioning of these lines (Table 6).

Table 6

Genetic indicators by lines of the Hutsul horse breed

Line	GO-RA-LA	GROBY			GURGULA			OUSORA		
Offspring of stud stallions	85 Pedro	Total	84 Pegazik	Grobj XV-10 SK/Astor	Total	81 Orlyk 024	74 Merkur G E 2-8	Total	82 Ousor Vulkan	52 Varnik 255
n	9	36	33	3	28	17	11	23	18	5
Na	4,000	6,000	6,000	2,000	6,000	5,000	5,000	6,000	4,000	5,000
Ne	2,051	3,692	3,594	2,000	3,960	2,714	3,781	3,380	2,842	3,846
Ca	0,488	0,375	0,278	0,5	0,253	0,369	0,265	0,296	0,352	0,26
I	0,974	1,520	1,466	0,6	1,497	1,191	1,424	1,396	1,176	1,471
H	0,049	0,004	0,005	0	0,008	0,017	0,008	0,004	0,006	0
W	0,101	0,010	0,017	0	0,030	0,047	0,031	0,013	0,018	0
Ho	0,556	0,861	0,848	1,000	0,786	0,706	0,909	0,913	0,889	1,000
He	0,512	0,729	0,722	0,500	0,747	0,631	0,736	0,704	0,648	0,740
Def	-0,044	-0,132	-0,126	-0,5	-0,245	-0,075	-0,173	-0,29	-0,241	-0,26
uHe	0,542	0,739	0,733	0,600	0,761	0,651	0,771	0,720	0,667	0,822

The highest level of polymorphism in our line Gurgul (Ne – 3.960), the average level in the line Grobi (Ne – 3.692) and in the line Ousor (Ne – 3.380). The lowest in the line Goral (Ne – 2.051).

The highest coefficient of expected homozygosity (Ca) in the line Goral (stallion-stud stallioning 85 Pedro) (Ca – 0.488), the lowest in the line Gurgul (Ca – 0.253). And if by stallions-stud stallioning, then the highest in the line Grobi (stallion-stud stallioning Grobi XV-10 SK/Astore (Ca – 0.5)).

According to the indicator of homozygosity realization (W), it is the highest in the Goral line (W – 0.101) in the stud stallion 85 Pedro, the lowest in the Grobi line (W – 0.010).

The deficit of homozygotes in our country was the highest in the Ousor line (–0.29).

Discussion. Most cultural and historical arguments for conservation are not based on genetic information, but our study results can be used in the development of a breeding strategy for horse breeding in Ukraine. Various molecular genetic studies, as well as



immunogenetic studies, allow us to follow, and even further control, the movement of markers from generation to generation from the ancestor to the offspring. Such work is carried out in parallel with the latest DNA technologies, which complement each other.

Since there are only a few genetic studies of the endangered Hutsul horse, the aim of this work was to provide new information to horse associations about the population structure, genetic characteristics and genetic origin of the Hutsul horse, as well as its relationship among other horse breeds. We hope that our results will be useful for conservation plans and breeding strategies for the breed.

As a brief summary of our results, we conclude that the immunogenetic analysis of each of the four studied lines of the Hutsul breed has its own specific feature in the distribution of alleles of the D-system of the blood group.

Conclusions:

1. All four lines of the Hutsul breed of horses have a unique, reliably different, immunogenetic profile.

2. In the genealogical lines of the Hutsul breed of horses, the transmission of alleles was inherited as follows:

a) in the Grobi line of the heir of the stud stallion 84 Pegazik, the Ddg allele was transmitted to his 14 offspring of stallions, and the Ddk allele to 19 offspring. In the heir of the Grobi XV-10 SK/Aster, the Dd allele was transmitted to 3 offspring, and the Dcgm allele was not transmitted;

b) in the line of the heir of the stud stallion 82 Ousora Vulkan, the Dde allele was transmitted to 6 offspring of the stallions, and the Ddg allele to 12 offspring. In the heir of 52 Varnik 255, the Ddg allele was transmitted to one offspring, and the Dcgm allele was transmitted to 4 offspring;

c) in the line of the heir of the stud stallion 81 Orlyk 024, the Dde allele was transmitted to 3 offspring, and the Dcgm allele to 14 offspring. In the heir of 74 Merkur Gu E 2-8, the Dde allele was transmitted to only 5 offspring;

d) in the line of the heir of the stud stallion 85 Pedro, the Ddk allele was transmitted to 8 offspring, and the Dde allele to one.

3. The highest frequency of the Ddk allele in the Goral line (stud stallion 85 Pedro) ($q=0.667$). High frequency of the Ddk allele in the Grobi line from the heir of the Grobi stallion XV-10 SK/Astor ($q=0.500$) and throughout this line ($q=0.431$). The highest frequency of the Dcgm allele throughout the Gurgul line ($q=0.357$). High frequency of the Dcgm allele in the Ousor (Poland) lines (stud stallion 52 Warnik 255) and Gurgul (stud stallion 81 Orlyk 024) lines ($q=0.400-0.529$) respectively. The Ousor line from the heir of the 82 Ousor Vulkan is characterized by a high frequency of the Ddg allele ($q=0.500$) and throughout this line ($q=0.435$).

4. According to genetic indicators: the highest level of polymorphism in the Gurgul line ($Ne - 3.960$), the lowest in the Goral line ($Ne - 2.051$). The highest coefficient of expected homozygosity (Ca) in the Goral line (stud stallion 85 Pedro) ($Ca - 0.488$), the lowest in the Gurgul line ($Ca - 0.253$). According to the breeding stallions, the highest in the Grobi line (stud stallion Grobi XV-10 SK/Astore ($Ca - 0.5$)). According to the homozygosity realization indicator, the highest in the Goral line ($W - 0.101$) in the breeding stallion 85 Pedro, the lowest in the Grobi line ($W - 0.010$). The deficit of homozygotes in our country was the highest in the Ousor line (-0.29).

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